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A REPORT ON

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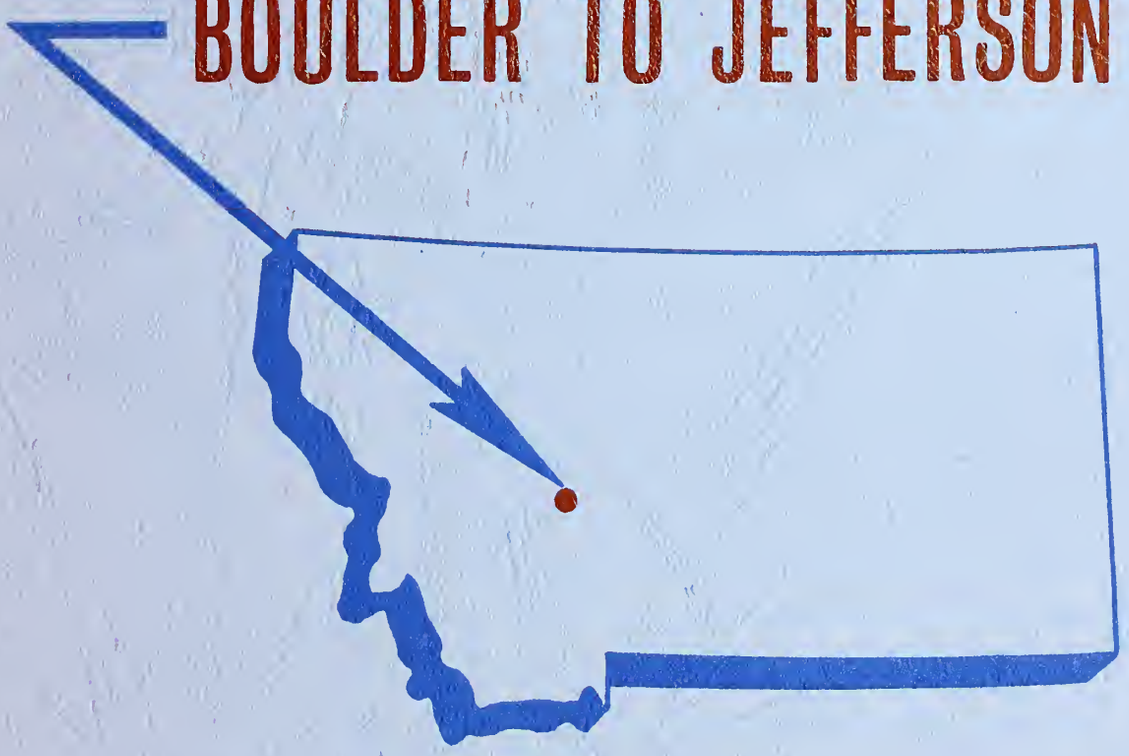
LOCATION AND DESIGN

BOULDER TO JEFFERSON CITY



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A REPORT ON

LOCATION AND DESIGN

BOULDER TO JEFFERSON CITY
INTERSTATE ROUTE 15

FEBRUARY 1965

PREPARED FOR

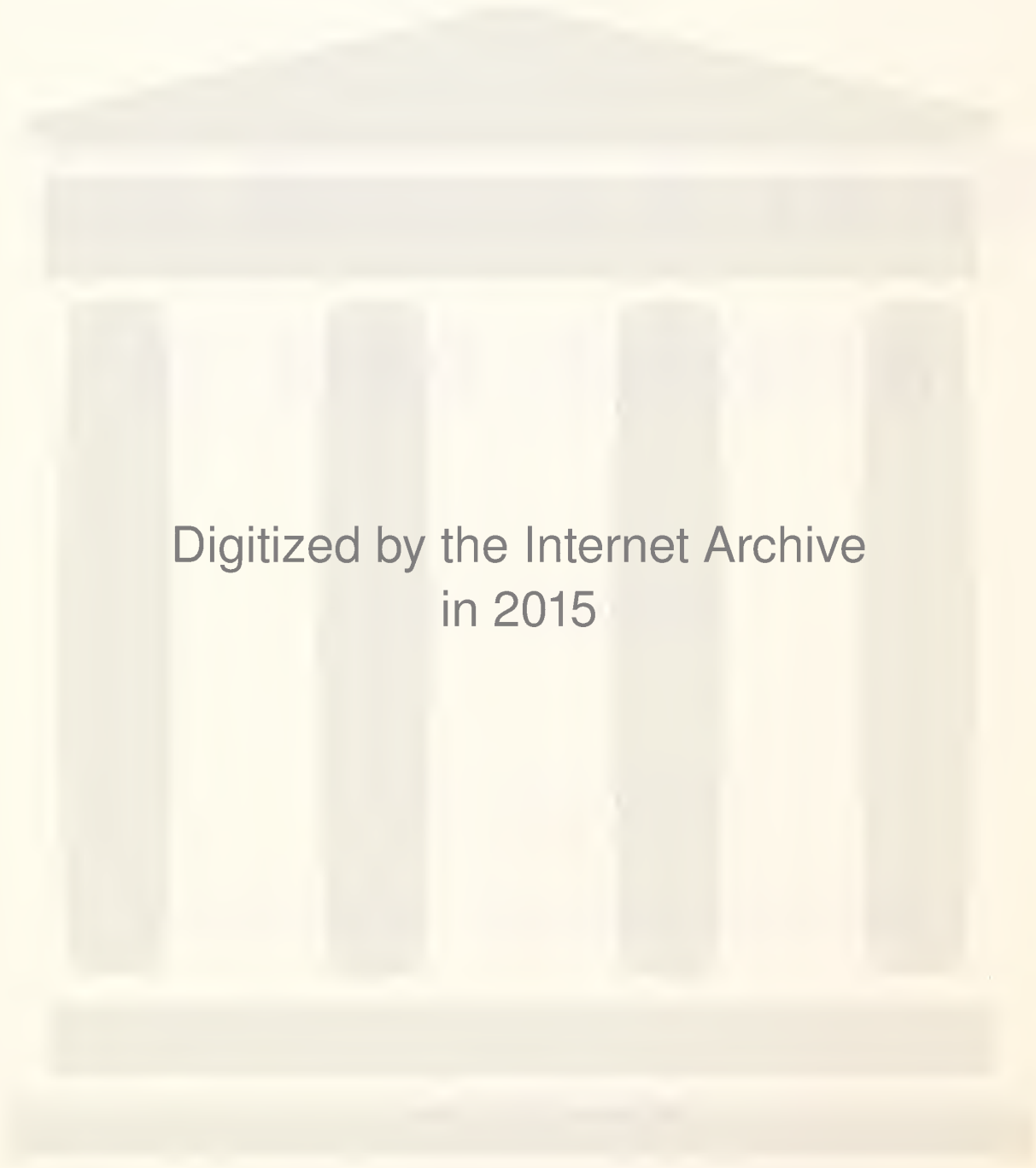
MONTANA HIGHWAY COMMISSION

PREPARED BY

MORRISON-MAIERLE, INC.

CONSULTING ENGINEERS

HELENA, MONTANA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CONSULTING ENGINEERS
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HELENA. MONTANA

STREETS
BRIDGES
AIRPORTS
HIGHWAYS
IRRIGATION
STRUCTURES
WATER SUPPLY
SEWERAGE WORKS
INDUSTRIAL WASTES

February 15, 1965

AREA CODE 406
PHONE 442-3050

Highway Commission
State of Montana
Helena, Montana

Gentlemen:

We are pleased to submit this preliminary engineering report on the location and design of the proposed Interstate Highway, Route 15 from the City of Boulder, Montana to the Town of Jefferson City, Montana.

This report presents recommendation for alignment, profiles and rest area locations on the various Interstate Highway locations considered.

For each alternate, a complete analysis was made of the cost, the service and the effect on local conditions. The report recommends design standards for the terrain encountered based on traffic studies and Interstate design criteria.

The alignment between Boulder and Jefferson City that is recommended in this report was chosen after comparisons of engineering and economic studies were made on all locations.

We sincerely appreciate the opportunity to perform this important study, and gratefully acknowledge the cordial cooperation and the valuable assistance of the officials and staff of the Montana State Highway Department, The Bureau of Public Roads, and members of the Highway Commission.

Respectfully submitted,

MORRISON-MAIERLE, INC.

John H. Morrison

J. H. Morrison, President

J. A. Maierle

J. A. Maierle, Secretary

JAM: jf

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A REPORT ON LOCATION AND DESIGN

Foreword

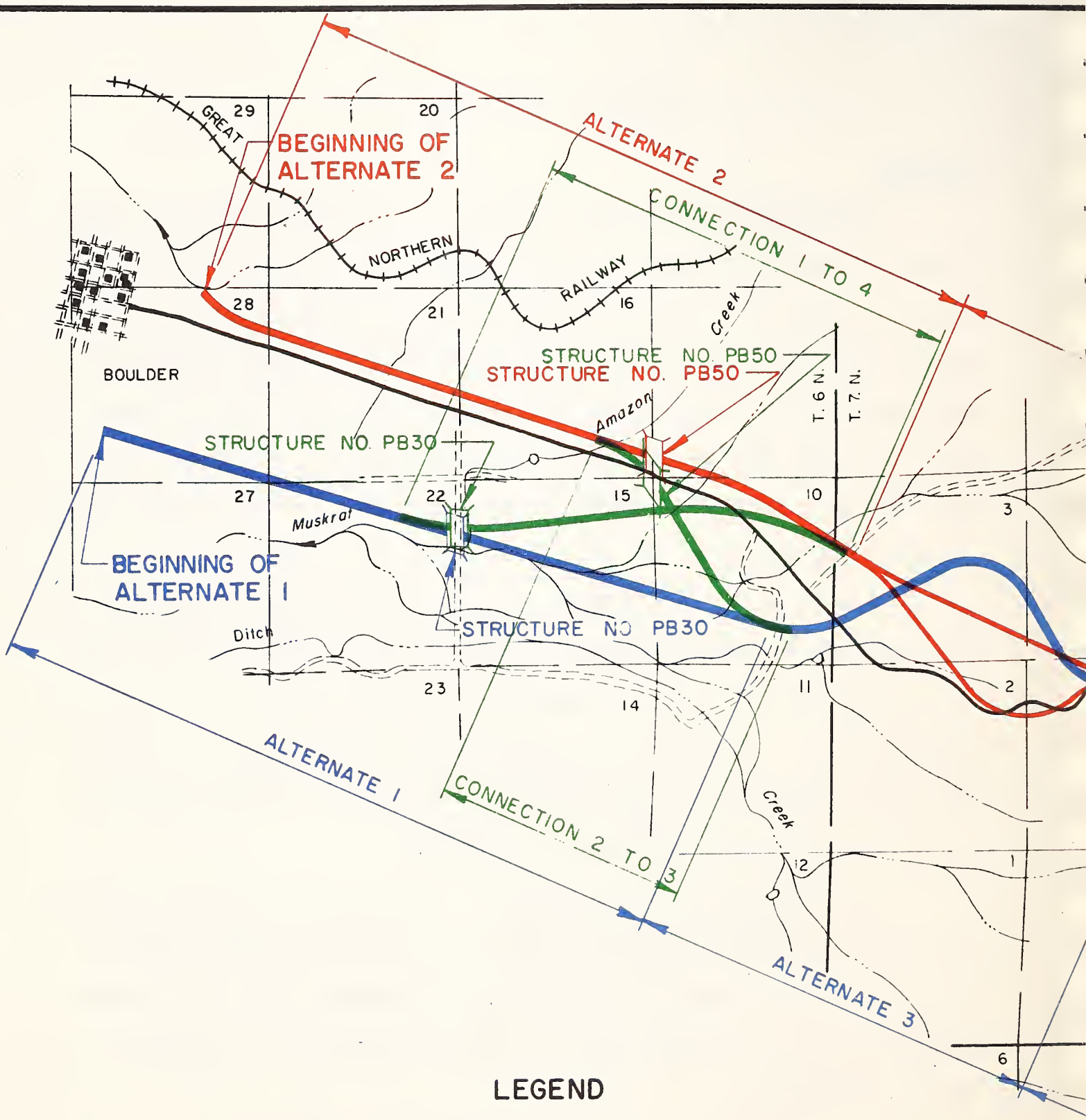
The authorization for this report is an agreement between the State of Montana, acting through its Highway Commission and Morrison-Maierle, Inc., Consulting Engineers. Interstate Route 15 enters southern Montana at Monida, goes through the cities of Butte, Helena and Great Falls and terminates at the State's northern boundary at Sweet Grass. The area of study lies approximately one-half the distance from Butte to Helena in Jefferson County and traverses a portion of mountains near 6000 feet in elevation known locally as the "Boulder Hill."

The purpose of this report is to present the specific recommended location for the Interstate Highway from the project beginning one mile north of the city of Boulder to the project terminus one mile south of the town of Jefferson City. The eleven mile project covered by this report is within the section designated by classification of the Montana Highway Department as Preliminary Engineering Project I 15-3(3) 157.

The information herein presented is the result of extensive engineering studies conducted by the Consultant of all possible highway locations within the corridors specified in the formal agreement. The study includes information on the following items as they are related to all alternate locations considered:

1. Geometrics
2. Soils & Geology
3. Drainage
4. Major Structures
5. Relocations
6. Design Standards
7. Construction Cost Estimates
8. Economic Analysis
9. Rest Areas
10. Access Solutions

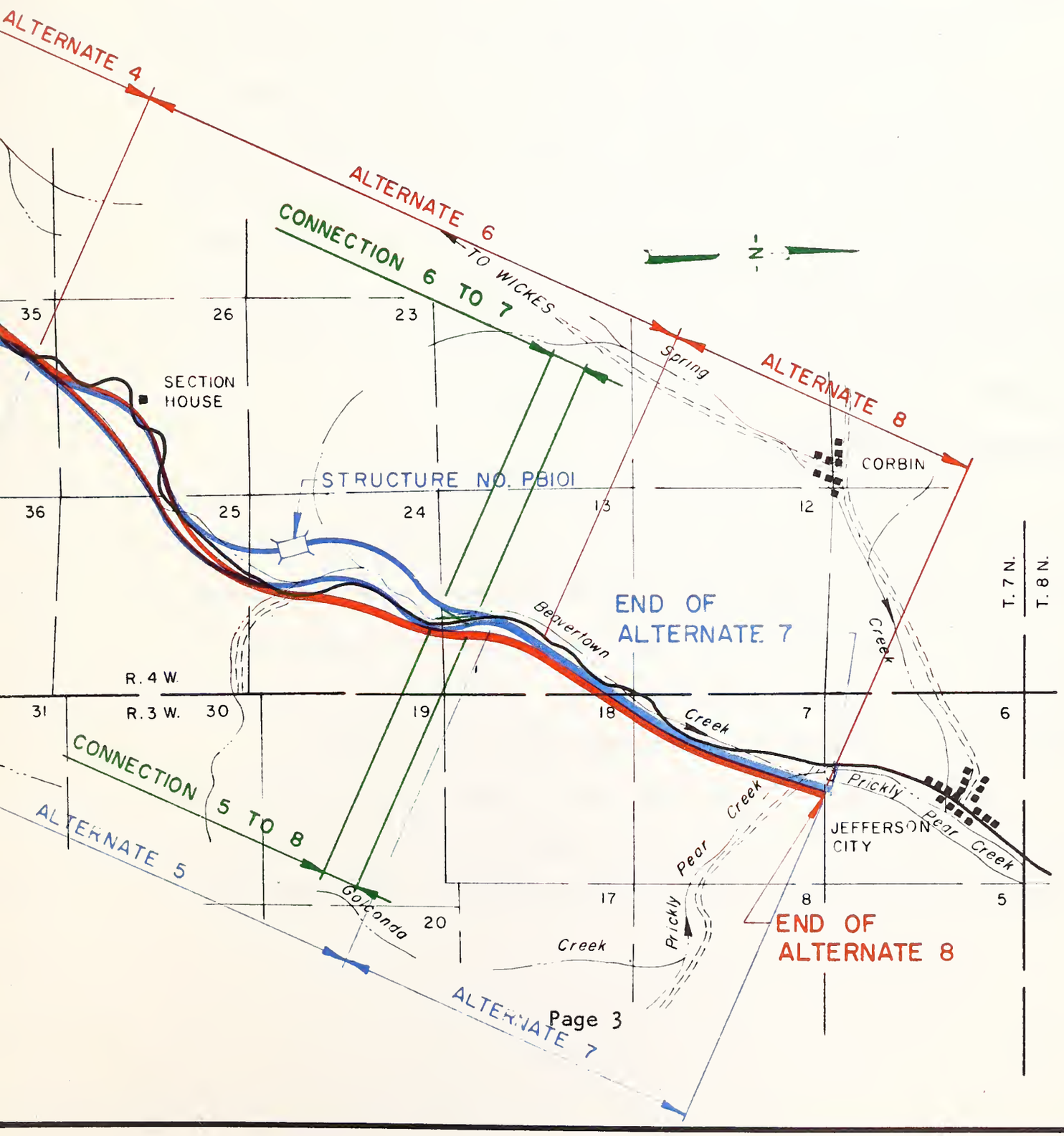
In order to avoid the expense of duplication of effort all pertinent available data of the Montana Highway Department was used whenever possible.



LEGEND

EXISTING		INTERSTATE	
HIGHWAY	———	ALTERNATES 2-4-6-8	———
FARM ROAD	– – – –	ALTERNATES 1-3-5-7	———
RAILROAD	+++++++	STRUCTURES	———
STREAMS	~~~~	CONNECTIONS	———

LOCATION PLAN
OF
ALTERNATES STUDIED
INTERSTATE 15
BOULDER TO JEFFERSON CITY



EXPLANATION OF EXHIBITS

Explanation of Key Plan

The map entitled "Location Plan of Alternates Studied" serves as a key plan drawing to show the lines or locations which were studied in detail and to show their relationship to each other and to other features in the vicinity.

An Alternate, as used in this report, refers to just a portion of the project length. The Alternates, for clarity and ease of notation, are divided into four pairs. Alternate 1 is paired with Alternate 2, 3 with 4, 5 with 6 and 7 with 8. The combination of one of each of these pairs comprises a total Alignment from beginning to end. For instance, the Recommended Location is Alignment 2-4-6-8. The words Alternate, Alignment and Recommended Location will be used repeatedly throughout this report and will represent this identical definition in every case.

Explanation of Plan-Profiles

The Plan-Profile illustrations shown are divided into two Alignments. The first is the Recommended Alignment which consists of Alternates 2, 4, 6, and 8. The other Alignment shows the other alternates that were studied, 1, 3, 5 and 7. Another road of interest is the access road planned from the northbound rest area to the airway beacon. The Plan-Profile drawing of this service road is shown at the station along which it is proposed.

Connections other than those used to connect the depicted Alternates 2, 4, 6, 8 and 1, 3, 5, 7 are shown on a separate plan. It is possible for a connection to be made, for instance from Alternate 1 to Alternate 4 or

from Alternate 2 to Alternate 3. These connections between the first pair of alternates and the second pair of alternates along with the connections between the Alternates 5, 6, 7 and 8 are shown following the Plan-Profile drawings. The costs of these connections are included in the summaries. Since the alignments and grades are the same where Alternates 3 and 4 join 5 and 6 at the top of Boulder Hill, no connections are required at that location.

GEOLOGY

Purpose and Method of Study

This phase of the Boulder-Jefferson City study was initiated in order to provide basic information regarding the geology and terrain traversed by the studied routes. Maps published by the U.S.G.S. Minerals Investigation Branch were used as a field aid and information noted was referenced to them. A field reconnaissance of all studied alignments was made. In addition to the geology, conditions relating to soil cover, groundwater and other pertinent field data were noted. The collected field information does not appear in this report as a single compilation. Where applicable, it is incorporated into the various design elements.

Topographic and Geologic Setting

Three distinct topographic areas are recognized. These areas include:

1) The broad intermentane Boulder Valley in the vicinity of the town of Boulder in the southern part of the area.
2) The subdued mountainous divide of the Boulder Hill region in the central portion of the area.
3) The narrow confined valley of Beavertown Creek-Prickly Pear Creek in the vicinity of the town of Jefferson City and southward.

The entire study area between the town of Boulder and Jefferson City occupies a drainage basin between two north-south trending mountain ranges - the Elkhorn Mountains on the east and the Boulder Mountains on the west. A linkage between these two mountain ranges is represented by

the Boulder Hill area. Boulder Hill divides the drainage in the central portion of the area. Waters on the south side of the hill enter the Boulder River and the waters on the north enter Beavertown Creek drainage. All waters are eventually drained by the Missouri River.

The region included in this study lies within the Boulder Batholith. The Batholith is a relatively young feature having been implaced during the waning period of the Rocky Mountain uplift. It covers approximately 4000 square miles. Only the northern fringe of the Batholith is of concern to this report. The typical rock found within the area is quartz monzonite. Because of its close affinity to granite, no problem, other than academic, will result from using the term granite in reference to the rock of the area.

The Batholith is a complex geologic phenomenon. The cooling of this massive body, beneath thousands of feet of overlying rock, set up internal forces which expressed themselves as fractures upon cooling. As erosion removed the overlying material, expansion of the body created more fracturing. The result was the complex fracture pattern evident throughout the Batholith. These systems of fractures are referred to as joints. Because the joints represent planes of weakness in the rock mass, they are of importance to this study. More important than the jointing is the problem of the weathering of the granite. The term weathering as used here, alludes to the chemical and physical disintegration of rock. The study of these two surficial expressions, weathering and jointing, determined the final recommended backslope design of this report.

Photo 1 and 2 - The crawler operator sets the ripper tooth into the rock. Note the smoke coming from the extreme friction of the tooth.

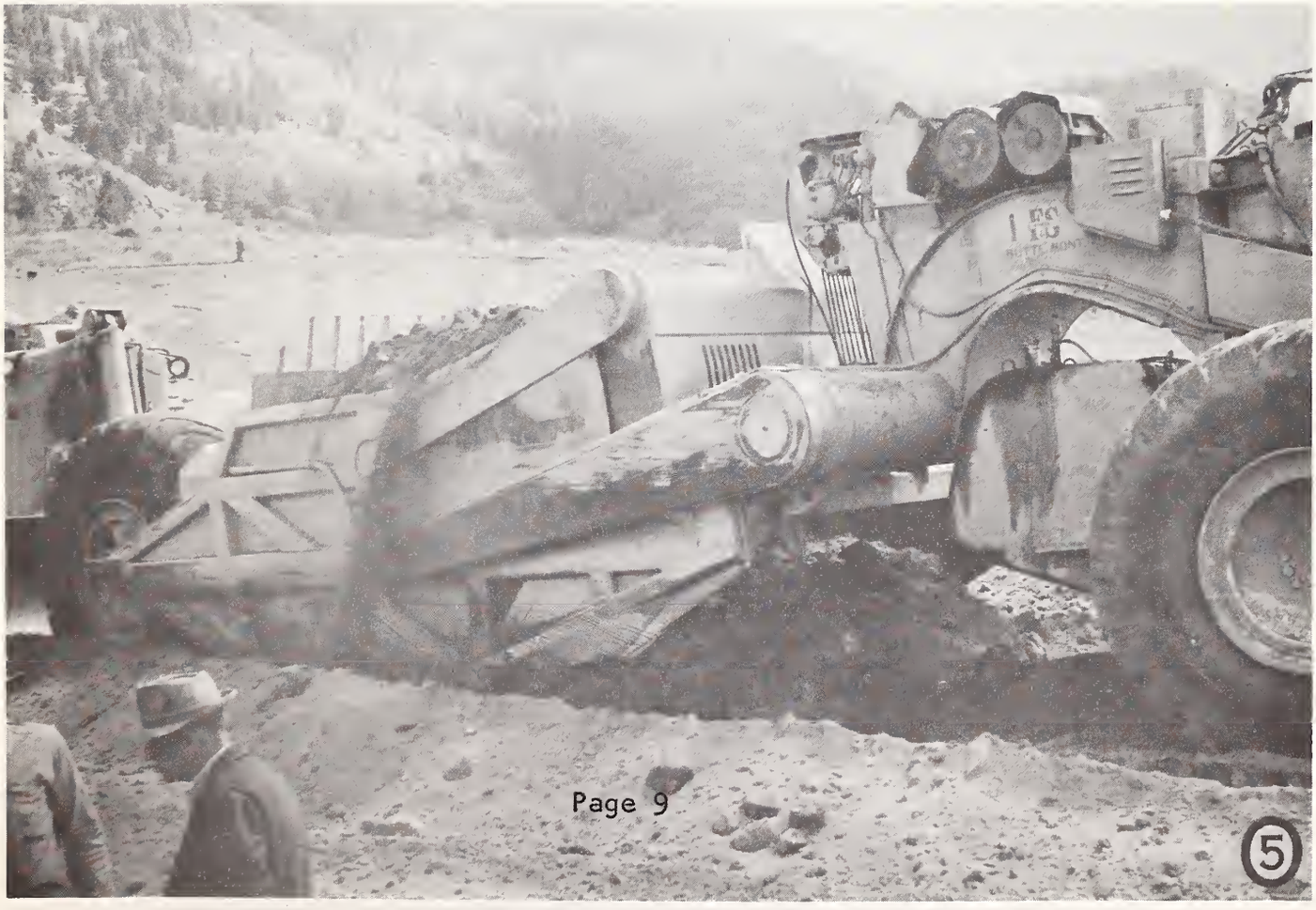
Photo 3 - After a single pass the weathered bedrock has been uprooted in chunks of a cubic foot or less.

Photo 4 - The crawler continues to rip in the area.

Photo 5 - The weight of the crawler has reduced the rock to virtually a sand by the time the scraper can pick it up.

These photos were taken on the Butte North Interstate Highway Project in an area expected to be similar in soil material to the Boulder Hill Project.

4



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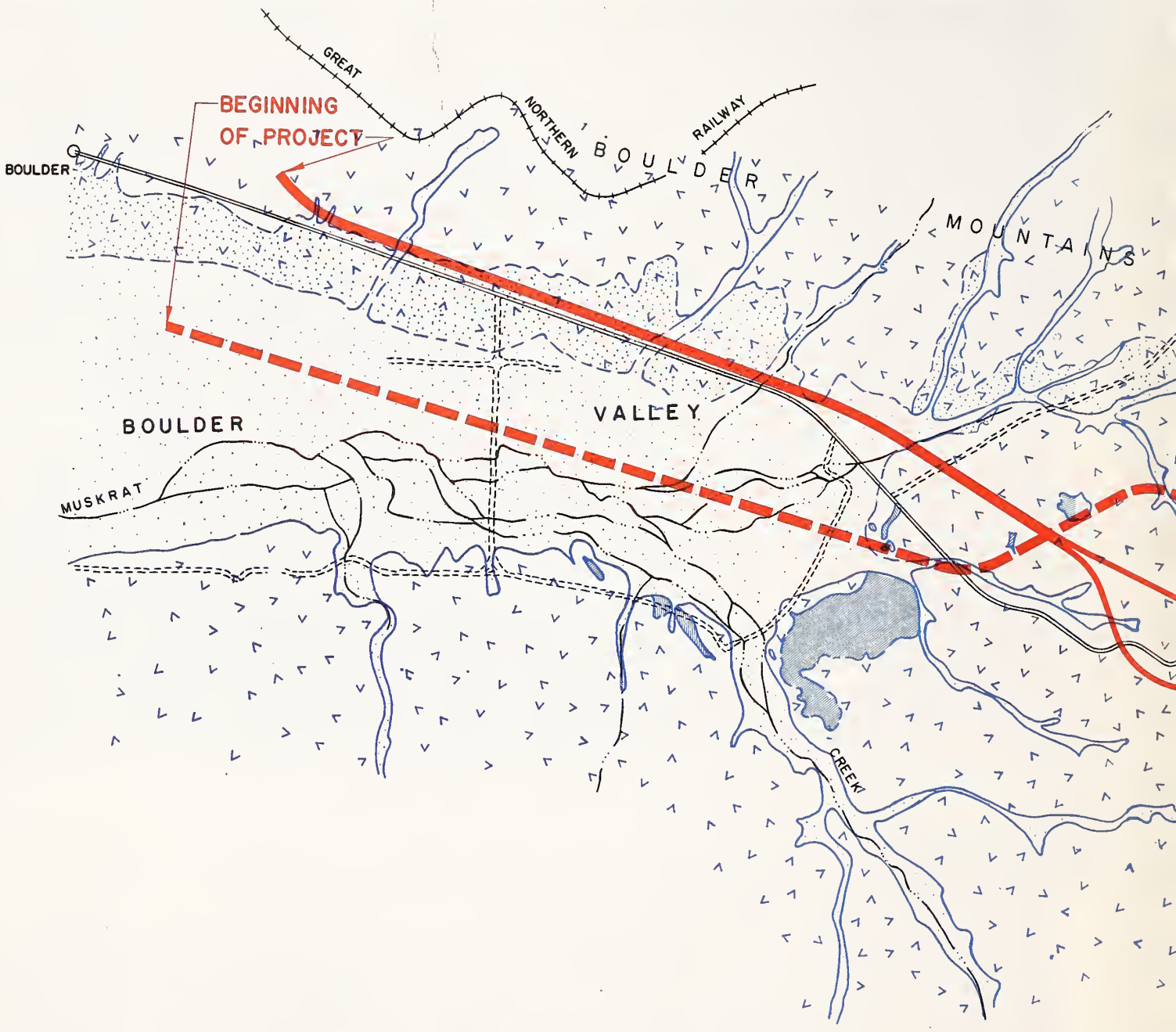


EXPLANATION

Stream bed alluvium. Composed predominantly of granitic gravels, sands and silts. In general the depth of this material increases downstream.

Non-transported alluvium. Composed of boulder gravels mixed with overburden soils. Depth is generally shallow.

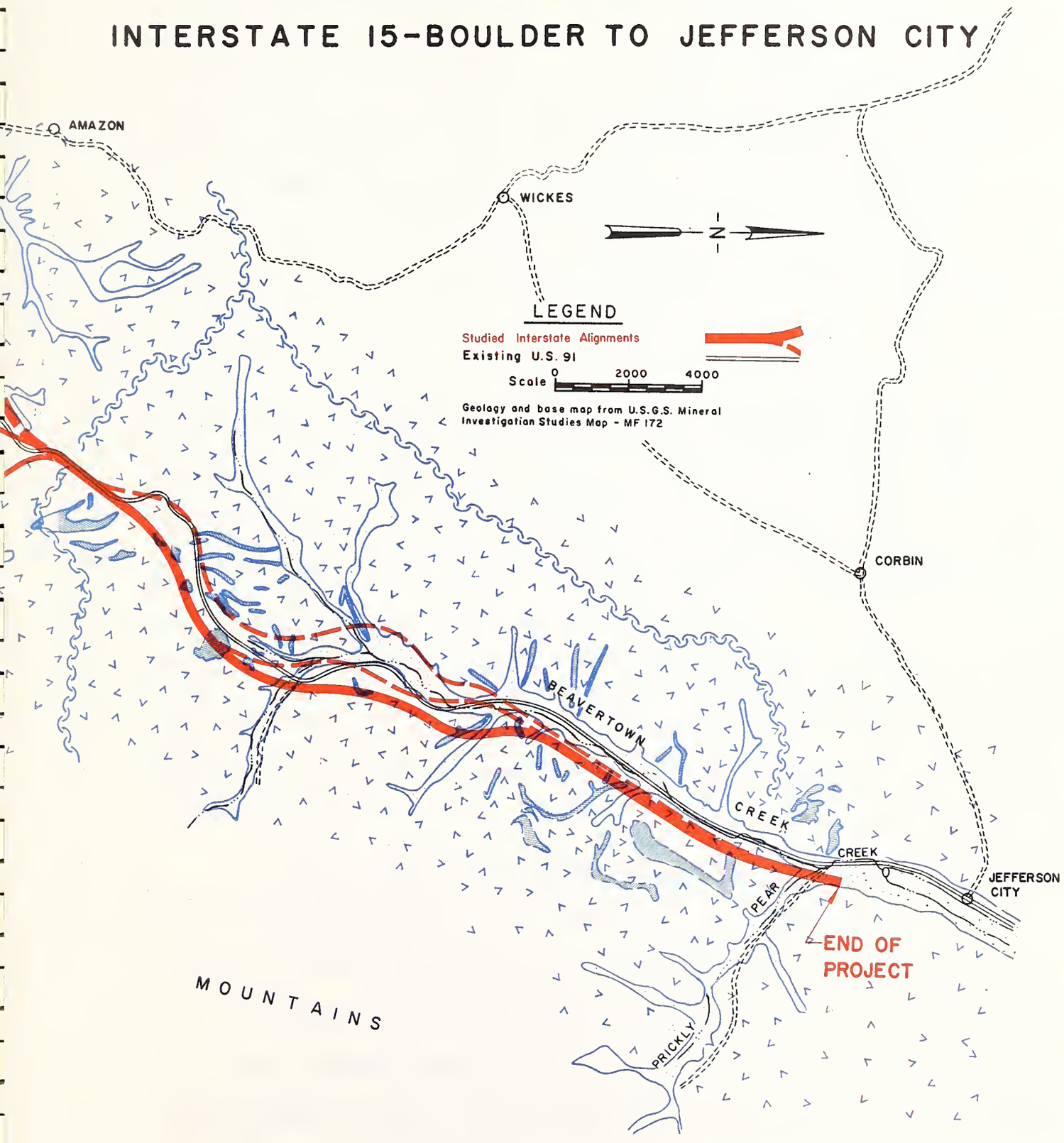
Boulder Bathalith Granite. Local soil cover variable in depth.

Intrusive rock. Material is more resistant than granite. Normally forms crests of major ridges.

Drainage Divide

GEOLOGY EXHIBIT

INTERSTATE 15-BOULDER TO JEFFERSON CITY



Results and Conclusions

As stated previously the entire study area is composed of rock related to the Boulder Batholith. By far the great majority of the rock to be encountered by all routes will be granite. Small dikes of more resistant rock such as aplite were noted. These dikes occur in profusion on the north slopes of the Boulder Hill and have a marked effect on the topography. Almost invariably, the prominent ridges and drainage divides normal to the Beavertown Creek valley are the result of the resistance of this material to weathering. It is not anticipated that any of the studied alignments will encounter any large dikes of this material.

Faulting, expressed by tangential movement along jointing planes is of no consequence to this study. Undoubtedly, major faulting has occurred in the region and evidence of some faulting was noted in existing roadcuts. The Boulder Hill area is stable and shows no signs of any recent tectonic activity. An apparent spring line in the Boulder Valley crosses the proposed alignments in a NW-SE direction indicating a possible fault line may be present in this portion of the basin. Although no fault movements are expected, the possibility of faulting is always a consideration in any area of the Rocky Mountains.

The Problem of Design of Backslopes in Weathered Granite

Proposed roadcuts in the granite of the Boulder Batholith demanded special study. This was emphasized by the difficulties encountered by contractors working on Interstate alignments in adjoining areas within the Batholith. As a part of this study, completed highway roadcuts were investigated as were highway projects under construction. Quarry sites and rail-

roadcuts were also studied and photographed for comparison purposes. The findings are summarized below. The results, where applicable, are incorporated in the recommendations of this report. The Consultant is grateful to the Butte Division of the Montana Highway Department for its cooperation during this phase of study.

The overwhelming tendency of the granite is to disintegrate to platy sheets which separate and crumble to course sand. Upon exposure to the climatic elements inherent to this region, fresh appearing granite will, in a matter of months, weather in the above manner. This process is greatly aided by the complex joint patterns.

Any granite rock face steeper than 35 degrees (the approximate natural angle of sand repose) allows easy removal of freed material which builds up along its base. In exposures where the rock face is flatter than 35 degrees there is a very marked reduction of talus and sand accumulation.

All anticipated rock excavation will be in weathered granite. Only minor exceptions for aplite dikes were recognized. Joint and fracture planes will have an adverse effect in the majority of proposed excavation sites. This is due primarily to the planes of weakness dipping into the proposed roadway cuts.

Studies of the weathering of granite by noted authorities indicate that although chemical reaction takes place in the form of oxidation and hydration, the volume change is extremely small.

It has been the experience in "working" the granite that when high explosives are used in construction, the rock literally disintegrates to sand and huge boulders. The boulders in many instances must be individually drilled and blasted for removal.

Recommendations

All of the alignments traverse similar geologic terrain. Recommendations with regard to the geology are applicable to all alignments and therefore considered a constant factor in the selection of the recommended alignment.

With regard to design:

1) All backslopes in cuts exceeding 45 feet in depth should be benched.

2) A multiple backslope design of $1\frac{1}{2}$:1 cut slope on the roadway section and 1:1 cut slopes on the bench section (where applicable) is recommended in order to reduce the rock and sand buildup, stabilize the backslopes and reduce the hazard of adversely positioned joint planes.

3) All other areas of excavation and embankment should use interstate standards in slope design.

4) Installation of adequately designed drains where ground water is anticipated will prevent strength reduction of the subgrade material.

HYDRAULICS & DRAINAGE

There are no major drainages in this project. All run-off can be carried by culverts. The largest culvert planned is the 132 inch diameter culvert required to carry Beavertown Creek. This creek begins at a spring near the crest of the ridge traversed by the alignments in this study. It flows northerly to Jefferson City where it joins Prickly Pear Creek. The flood design flow was based on an estimated 1500 cubic feet per second.

A figure of $15,000 per mile has been used as an estimate for small drainage structures under 60 inches in diameter. All pipes over 60 inches in diameter were computed individually employing Bureau of Public Roads criteria as set forth in "A Simplified Method For The Hydraulic Design Of Culverts." The basic design criteria was a 25 year rainfall intensity of 1.10 inches per hour and a run-off coefficient of 0.19 suggested for slopes of 15 to 30 degrees. The discharge obtained with these values from the U.S.B.P.R. data has been multiplied by 1.2 to obtain maximum discharges for a 50 year frequency storm.

A number of springs are expected to be encountered on any location through this area. The flows of these springs are not large. However, consideration must be given in the design stages of this project to alleviate any possible spring problems. Perforated interceptors or other pickup devices can successfully be placed in the backslopes and roadway prism to keep the earth dry and eliminate sagging or creeping of the material.

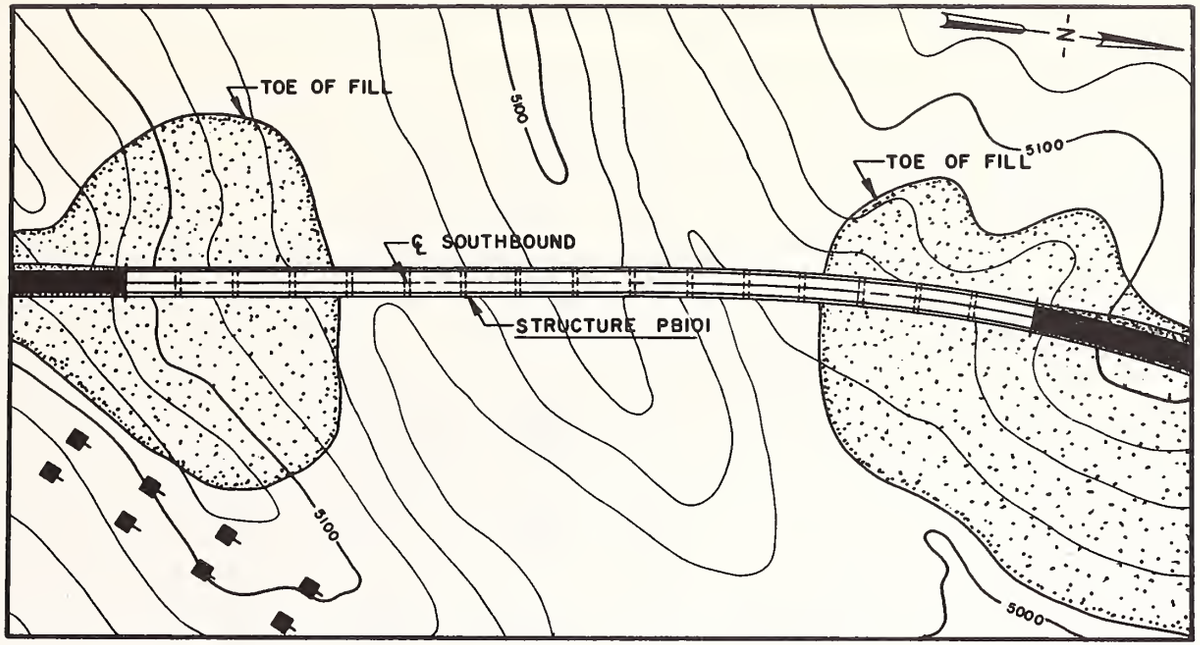
MAJOR STRUCTURES

The three major structures required on various alternates are not drainage structures. Two of the structures are to provide local access. The third is a bridge used in lieu of a huge earth fill which would otherwise be required.

One each of the two access bridges would be required for the local road to cross over the Interstate on Alternates 1 and 2. These structures would be the same as the many basic precast prestressed bridges that have been built and are being planned on the Montana Interstate system. Because of this, no structure plans or details are shown in this report for these structures. The access provided by these structures will be discussed in the section entitled "Access."

The other structure is on Alternate 5 over a large, normally dry, draw. It was planned with an excavation reduction in mind. With fill slopes at 2:1, high grades involve large embankment volumes. Computations showed that when the profile grade was above the ground 80 feet or more, a reduction in embankment and a reduction in excavation could be made by using a bridge that would reduce the cost of grading by more than the increased cost for a structure. A drawing of this bridge PB101 shows some of the details of this structure.

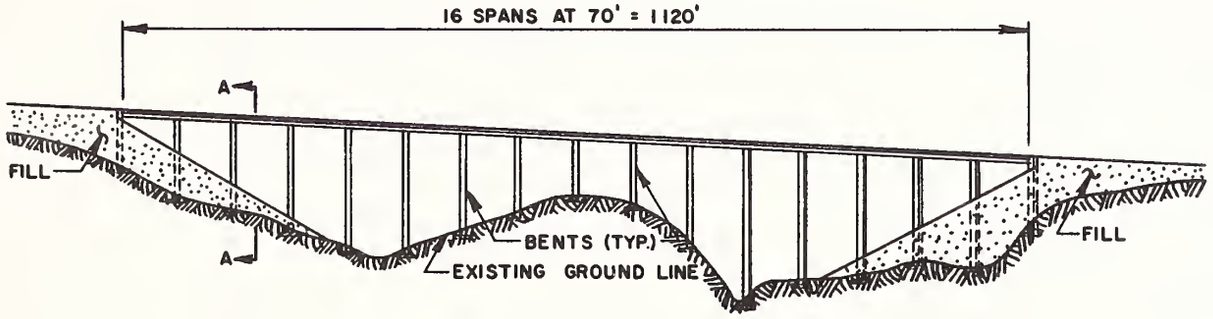
The cost of the access structure over Alternate 1 is $95,000, and for Alternate 2 it is $100,000. The cost of the bridge on Alternate 5 is $650,000.



PLAN VIEW

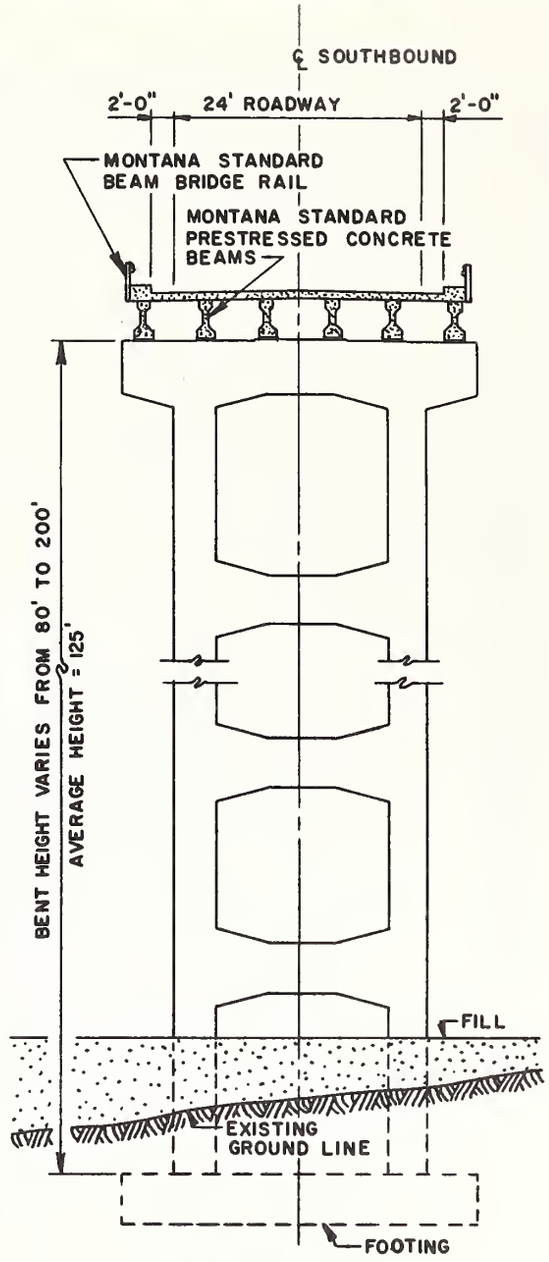
0' 50' 100' 200' 300'

CONTOUR INTERVAL = 25'



ELEVATION

0' 50' 100' 200' 300'



SECTION A-A

SCALE: 1" = 20'

STRUCTURE PB101

INTERSTATE 15 - BOULDER TO JEFFERSON CITY

DESIGN STANDARDS AND CRITERIA

General

Design criteria are based on those acceptable for the Interstate System. This is outlined in the pamphlet entitled "Geometric Design Standards for the National System of Interstate and Defense Highways" adopted by the American Association of State Highway Officials (A.A.S.H.O.) and the U. S. Department of Commerce, Bureau of Public Roads. This is the criteria used on Interstate Highways throughout the Nation which involve the use of Federal Aid funds. Incorporated as design guides are the book publications of A.A.S.H.O., "Policy on Geometric Design of Rural Highways," and "Standard Specifications for Highway Bridges." The "Field and Office Standards" and "Standard Drawings" publications along with other current written standard practices of the Montana Highway Department are also used as guidelines.

Design Conditions

(1) Type of Terrain - Flat and Rolling

(2) Design Speed - 70 MPH and 60 MPH

(3) Traffic Lane Width - 12 feet

(4) Traffic Data (From Montana Highway Commission Planning Survey Division)

Year 1962 Average Daily Traffic	(ADT 1962)	941 vehicles
Year 1988 Average Daily Traffic	(ADT 1988)	3150 vehicles
Commercial Vehicles as a % of ADT		17.5 %
Year 1988 Design Hourly Volume	(DHV 1988)	460 vehicles
Commercial Vehicles as a % of DHV		13 %

(5) Number of Traffic Lanes 4

(6) Typical Roadway Sections See Figure 58

Typical Roadway Sections

The typical sections used on the various alternates are illustrated on the drawing entitled "Typical Highway Sections" Figure 58.

The paving section in each direction is planned for a 4-foot median shoulder, two 12-foot traffic lanes, and a 10-foot outside shoulder bordering a 25-foot ditch. The median width will vary.

The 25-foot ditch is planned for snow storage as well as a catch for material coming from the backslopes. The volume of snow expected from snowfall in this area is not extremely large compared to other similar areas. Yet, the experience of the Highway Department indicates that drifting onto the highway is excessive.

The geology section of this report describes the material through which the roadway must be constructed. This material possesses inferior stability. Sloughing of the backslopes can be expected as weathering occurs regardless of the angle of backslope. However, the design recommended, which incorporates the bench, and the slopes as shown in the drawing, will reduce the sloughing to a practical minimum.

The backslopes shown were used on all alternates. Standard Interstate backslopes in a ratio of two to one (2:1) would be more stable than steeper slopes of $1\frac{1}{2}$:1. However, this would require excessive earthwork yardages. The use of the compound slope shown with the bench will require less material excavation than if the $1\frac{1}{2}$:1 slope is carried all the way up the backslope. An adequate bench for periodic maintenance as shown will not only reduce the required excavation but will also retain sloughing material above the roadway ditch. Retained here it would be much less objectionable from the standpoint of appearance. The probability of falling rock reaching the roadway and resultant hazard is also reduced.

Spiral transitions are used at both ends of all horizontal curves sharper than one and one-half degrees. The rate of superelevation will not exceed 0.08 foot per foot. This is based on consideration of these factors: climatic conditions, terrain, type of area and frequency of slow-moving vehicles. Transition to full superelevation will occur within the spirals or in a runoff distance beyond the beginning and end of curves without spirals. Vertical curve lengths are based on 150 times and 250 times the algebraic difference of grades expressed in percent for sag and crest curves respectively.

A 600 foot stopping sight distance is recommended since very little of the roadway over Boulder Hill will be on a tangent. Longer than minimum vertical curves provide additional safety. This feature can be incorporated without excessive cost.

The swell factor used in the excavation over Boulder Hill is 15%. In the valley immediately north of the city of Boulder, Alternate 1 earthwork has a shrinkage factor of 20% and Alternate 2 earthwork has a swell factor of 0%. As pointed out in the geology section, the rock material is presently weathered rock and will excavate as rock. However, after it has been disturbed it will readily reduce to a sand-like material. For this reason fill slopes will not be constructed at $1\frac{1}{2}$:1 which is commonly employed for rock embankments. Instead, 2:1 fill slopes have been used on all alternates.

The maximum ascending gradient is 5%. The maximum descending gradient is 6%. These maximum grades were used on all alternates since this terrain cannot be considered rugged, and therefor steeper grades are not warranted.

GEOMETRICS AND LOCATIONS

General

The area of study traverses a drainage divide 5700 feet in elevation. Preliminary studies were made by the Montana State Highway that concluded that the most feasible location to cross this divide was at the crossing made by the existing U.S. 91. Design features as they relate to topographic features were the only other location restrictions.

Preliminary evaluation of prospective locations on the site and on topographic maps resulted in the decision to study in detail the alignments shown on pages 2 and 3 and described in the following text. Considering each alternate separately, cost estimates for a total of 27.34 miles of separate, distinct and unduplicated lines were computed and tabulated and are reported. The same extent of detailed consideration regarding grades, cross-sections, curves, drainage structures, etc., was accorded all alternates.

Alternate line study was made from photogrammetric reconnaissance maps furnished by the Montana Highway Department. The contours on the maps were at 5 foot intervals except where steep slopes required intervals of 25 feet. The scale of the maps were at one inch equals 200 feet. Ground line profiles and cross-sections were plotted from these maps. Cross-sections in rocky areas or areas of heavy construction work were plotted at intervals of 100 feet or less. Most other cross-sections do not exceed several hundred feet between sections. Grades were laid and earthwork quantities were computed. The visual pictures of the cross-sections were extremely valuable for determining locations and estimating quantities.

Several locations were considered that do not appear in this report. It was realized at the commencement of the study that certain areas would necessitate study if only to prove their inexpedience. The amount of study on each of these locations varied and was carried only to the point of proven unfavorability. These locations are not described since these areas are numerous and cannot be considered pertinent to this report.

Rest areas for both the northbound and southbound lanes of travel were planned for the area covered by this report. The northbound rest area is located near the top of the hill on the south side; the southbound rest area is located near the top on the north side. Both are in existing meanders of the present U.S. 91.

The areas planned do, in both cases fit either alternate that they are adjacent to. The cost of the rest areas has no bearing on alternate selection. Each area is estimated to cost approximately $60,000. The cost is added into the summaries under the item "Earthwork."

Springs have been noted throughout the area and they could furnish water to the rest areas. However, this was not studied in detail. These springs do not flow enough water to create a construction problem, but consideration must be given to their discharge.

A summary has been prepared to show the geometric features of each alternate. It is labeled "Geometrics Summary" and is on Plate 2. It shows comparisons of length, grades and curvature.

Alternates 1 and 2

Alternates 1 and 2 extend from one mile north of Boulder across the north end of the Boulder Valley to the foot of the ascent of the Boulder Hill.

As two general areas are considered for locations south of this project, the Alternates 1 and 2 are located one in each of these areas. If the alternates came to a common point they would both be warped from the proper alignment.

Alternate 1 and Alternate 2 are the same length. The major difference between them is that Alternate 2 traverses the west side of the valley over grazing land which is a rocky type soil. Alternate 1 crosses good hay land in the bottom center of Boulder Valley. For this reason Alternate 2 has a lower right-of-way cost.

Alternates 1 and 2 are both 100 feet from centerline to centerline of directional pairs of lanes. Alternate 1 uses a common profile grade line. Alternate 2 has the southbound lanes profile grade 6 feet higher than the northbound lanes. This was done to reduce earthwork since construction will be on a 6% transverse sloped sidehill. This will provide a desirable split level grade alignment.

A structure over the Interstate will be required on each of these alternates. An access road will be required also. The costs of these access roads are included with the alternates in the cost summaries. The area served by these access roads is discussed under the heading denoted "Access And Right-of-Way."

At their termination, connections were computed that would allow either alternate to connect with the continuing Alternates 3 and 4. The cost of these connections is included in the summaries.

Alternates 3 and 4

Alternates 3 and 4 begin at the bottom of Boulder Hill on the south-side and end at the crest. Both alignments have individual grades for the

northbound and southbound pairs of lanes. Alternate 4 traverses a more rugged ground profile than does Alternate 3. For this reason Alternate 4 has a higher earthwork cost. However, because it is shorter, the operational cost to the road user is lower.

The airway beacon at the top of the hill must be served by an access road to maintain the facility. The access road is planned from a locked gate at the rest area. The road has a maximum grade of 12% and will be approximately one-half mile long. The plan and profile alignment are shown on Figure 15.

Alternates 5 and 6

Alternates 5 and 6 continue from the crest of Boulder Hill and the end of Alternates 3 and 4 to the bottom of the hill on the north side. Alternate 5 has separate grades and alignment for each pair of directional lanes. For most of its length one pair of lanes is on one side of the narrow valley and the other pair is on the other side. Alternate 6 is a 70 foot center to center section throughout most of its length. However, the two alternates are identical for the first 50 stations.

It is in the area where the alignments are identical that the southbound rest area is planned. The rest area is planned to occupy the area presently used by the Montana State Highway section house.

A major bridge structure would be required on Alternate 5. The structure would be to carry the southbound lanes over a deep draw. Computations were made with regard to the volume of embankment necessary to fill this area compared to the cost of the structure. It was found that by employing a structure, embankment could be reduced and a reduction of excavation would follow. The cost of reduced excavation would be more than

the cost of a structure. The results of the computation showed that a structure was more favorable where the fill height exceeded 80 feet. The length of the structure is 1100 feet and the cost is estimated at $650,000. It would be an extremely high bridge with supporting piers ranging from 80 to 200 feet in height with an average height of 125 feet. The length, height, and resulting cost tend to make this alternate less desirable than Alternate 6.

A frontage road would be necessary for either of these alternates. The service it provides will be discussed under the section entitled "Access and Right-of-Way."

Connections at the end of each of these alternates were evaluated so that either Alternate 5 or Alternate 6 would connect to both of the continuing alternates 7 and 8.

Alternate 7 and 8

Alternates 7 and 8 continue on from Alternates 5 and 6 at the bottom of the hill to the End of the Project immediately south of Jefferson City. Alternate 8 is a 70 foot center section while Alternate 7 has independent grades and alignment. Alternate 8 and the northbound lanes of Alternate 7 are on the easterly side of Beavertown Creek. The southbound lanes of Alternate 7 are between Beavertown Creek and the existing highway. Alternate 7 requires a channel change of Beavertown Creek. The creek would be rerouted to flow between the northbound and southbound lanes of Alternate 7. This is not considered a desirable feature. It cuts off the stream for stock water as well as having greater potential for hydraulic damage to the Interstate embankments.

The existing highway can remain to effectively serve as a frontage road for either alternate. This road will also serve as a part of the frontage road to points further south.

ACCESS AND RIGHT OF WAY

The access control of Interstate Highways is governed by the law which established the system and set the standards. It is one of the outstanding built-in safety features of these roads. Random access, turning and parking are not permitted and the right-of-way limits are fenced. Access to facilities of more than two lanes can be made only at interchanges. This characteristic has a direct bearing on the present and potential utilization of the land.

Because property values are a major cost item, and because considerations due property owners along a route are important, access to and from a parcel of land must be considered in highway location. A culvert large enough to allow a cow to walk through can sometimes open an area worth thousands of dollars in grazing land that would otherwise be isolated. It is for this reason that segregation and depreciation is considered as well as the actual cost of the right-of-way land.

Right-of-way cost estimates for ownerships in this project were prepared by the Montana Highway Department based on present conditions and future conditions assuming the various alternates were built. On this basis the lowest cost combination of right-of-way costs and provisions for access were worked out and included in the cost estimates. Required access roads and structures are shown on the Plan-Profile drawings.

Access to Alternate 1

Alternate 1 divides one 1200 acre ranch in half. If this is done, one-half of the ranch would be totally depreciated unless access is provided. A structure over the Interstate would be required at the point of crossing

of the county road between sections 22 and 15. A frontage road would have to be constructed to connect the road with the remainder of the farm. Alternate 1 also separates the grazing land from the hay land of a large ranch at the north end of the valley. This structure would conveniently provide the necessary access to this grazing land. The cost of this structure and access road is $95,000 and $6,000 respectively. The access road cost is included in the summaries with the Interstate costs.

Access to Alternate 2

Alternate 2 parallels the existing highway. It, too, must have an access structure so as not to segregate grazing land from hay land. This is applicable for two ranches. The structure also provides access from the City of Boulder to the town of Amazon and the adjacent vicinity. The structure cost is $100,000 and the connecting frontage road cost is $19,500. This cost of the frontage road is included in the summaries with the Interstate costs. The existing highway will, for both Alternates 1 and 2, remain as a frontage road.

Access to Alternates 3 and 4

The only access necessary on Alternates 3 and 4 is to the airway beacon for maintenance purposes. The access road will be attainable through a locked gate in the rest area. The access as well as the rest area will be the same for either alternate. The alignment and grade of this road is shown on Figure 15 in the Plan-Profile section of this report. The cost of this road is $13,300 and is included in the alternates in the summaries. No other access considerations have been made for Alternates 3 or 4.

Access to Alternate 5

Several points require access on this alternate. There is a rest area planned for the southbound lanes near the top of the hill which is the beginning of Alternate 5. However, no vehicular access is planned from the interstate in this area. At Station 588+00 an access pipe is planned under the northbound lanes to allow access into the area to the east of the new roadway. The frontage road to this area comes from the bottom of the hill where an access pipe at Station 650+00 would allow traffic to travel under the southbound lanes from the existing highway which would be used as a frontage road. Near this access pipe would be, also, an access pipe under the northbound lanes to furnish access to the farm that is here. The pipe underpass costs are included in the "Small Drainage Structures." The roadway cost, $12,600, is included in the cost summaries with Alternate 5.

Access to Alternate 6

Similar to Alternate 5, Alternate 6 will also require access to the area east of the new Interstate. As shown on the Plan-Profiles, the frontage road would be very nearly in the same location as for Alternate 5. Alternate 6 will not, however, require access under the northbound lanes at Station 650+00 due to the fact that the alignment is coincident with the farm buildings and the farm will probably be taken in the right-of-way. The pipe underpass costs are included in the "Small Drainage Structures." The roadway cost, $4,050, is included in the summaries with Alternate 6.

Access to Alternates 7 and 8

Alternates 7 and 8 will have the same access characteristics. To the west of both alternates the existing highway will remain as a frontage road and serve the underpass on Alternate 5 or 6. No access is planned to the east of these alternates as an access road would cost more than the value of the land with access compared to the value of the land without access.

ECONOMIC ANALYSIS

An economic analysis in the form of a cost comparison study is made to compare alternate locations or routes with similar terrain and design conditions. For a valid comparison, the type of highway facility and the traffic served should generally be the same. The result of this analysis is a cost comparison which proportions due consideration to the items that can be evaluated in terms of true cost in dollars.

More than the initial construction costs must be considered. This has long been recognized as revealed in the statement from "A Manual of the Principles and Practices of Road-Making" by W. M. Gillespie, published in 1846. To quote: "A minimum of expense is, of course, highly desirable, but the road which is truly cheapest is not the one which has cost the least money, but the one which makes the most profitable returns in proportion to the amount which has been expended upon it." In this study an evaluation of alternate locations is made on an annual cost basis. Major items to be considered are construction, maintenance, and vehicle operating costs. The various items considered in the initial construction costs are amortized over a certain life expectancy at a specific rate of interest. Maintenance involves costs which occur in the year performed and are primarily related to the length and type of facility. Annual road user costs are related to the number of vehicles using the facility and also the features and type of highway involved.

The residents in the immediate vicinity of a proposed highway improvement normally are interested and concerned with its location. Also the non-resident road user is concerned with the cost of construction and

maintenance since it is highway user taxes and fees which provide the major source of funds for highway facilities. The road user is also interested from the standpoint of vehicle operating costs.

This report evaluates road user costs for automobiles for different conditions of operation on highways of various types. These consider the following variables as tabulated in the 1960 A.A.S.H.O. Informational Report on Road User Benefit Analysis:

1. Type of Vehicle
   a. Passenger car.
   b. Truck or Bus.
2. Type of Area
   a. Rural.
   b. Urban.
3. Type of Highway
   a. Two Lane.
   b. Four Lane.
4. Type of Operation
   a. Free.
   b. Normal.
   c. Restricted.
5. Running Speed
   a. Range of likely values.
6. Gradient Class
   a. 0 to 3 percent.
   b. 3 to 5 percent.
   c. 5 to 7 percent.
   d. 7 to 9 percent.
7. Type of Surface
   a. Paved.
   b. Loose surface.
   c. Unsurfaced.
8. Alignment
   a. Tangent.
   b. Curved.

The referenced A.A.S.H.O. report assigns individual vehicle operational costs for ranges of profile grades as indicated by Item 6 above instead of for unit increments of profile grades. In order to more fully reflect the accelerating rate of increase in operation costs on steeper gradient, the values from the A.A.S.H.O. report were plotted for the average grade of each grade range. The curve determined by these points could then be used to obtain a value for any profile gradient. Average grade for the total alternate length was used to determine the unit operating cost.

The average annual daily traffic was considered to be the 1978 ADT which covers a 20 year period from 1968 to 1988, and is consistent with the above informational report. 1968 was used as a probable date of commencement of construction which makes 1978 the midpoint of the 20 year period considered.

The operating costs for commercial vehicles were considered at 3.5 times that for passenger cars. This value is the average of the range of values presented as a composite for trucks and buses outlined in Table 2 of the A.A.S.H.O. Informational Report. All unit costs of vehicle expenses were used as published in the A.A.S.H.O. Informational Report with the exception of the unit cost of gasoline, which was increased from 32 cents to 40 cents per gallon to reflect the current prices in Montana. Because 4 lanes are planned through the project, operation was considered "Free."

Unit maintenance costs for service roads were based on an assumed state of loose surface in good condition. Existing highway sections which will be retained for use in conjunction with the new service roads are paved roads. Since these roads may not be State highways, it is uncertain what type and extent of maintenance they will receive in the future. They may in time deteriorate to the equivalent of a gravel surfaced road. For this reason the existing highway was considered gravel for the unit maintenance cost.

Annual maintenance of the Interstate was estimated at $3,000 per mile. This is the sum of the average Interstate maintenance cost plus and adjustment for steeper than average grades.

Total annual construction costs and annual maintenance costs are

shown in the summary for the alternate locations. An interest rate of 6% was used as a basis of amortizing the initial construction costs over the service life of the various highway construction items. This is consistent with present practice of the Montana Highway Commission. The service life of each construction item is shown below:

1. Right of Way - 50 years
2. Grading and Drainage - 40 years
3. Major Structures - 40 years
4. Surfacing - 20 years

Because utility adjustment costs are not considered a contract construction item, they are included in the Right-of-Way costs.

No traffic movement layouts are included or required because there are no interchanges or other features which would change the main line traffic count. Operating costs on frontage roads were omitted because traffic would be so small that the costs of operation would have no effect in the analysis.

BASIS FOR CONSTRUCTION COST ESTIMATES

An estimate as complete and detailed as possible and within the realm of accuracy warranted by a preliminary engineering report was prepared for each alternate location of this study. In the cost summaries that compare the various alternates, the totals do not include allowances for engineering and contingencies. Each item has been estimated with the intention of being necessarily adequate.

Excavation costs vary directly with the amount of rock excavation anticipated. The costs range from $0.40 to $0.90 per yard for dirt and rock respectively. These prices include overhaul, watering and rolling. A careful geologic inspection with engineering construction procedures in mind was made of all locations considered. From this examination, areas of different per-yard excavation costs were established.

Since the surfacing section in an area with a rocky subgrade will be more capable of withstanding roadway pressures without deformation than will areas of dirt embankment, the surfacing section was altered with respect to the stability of the subgrade. The gravel weight, swell factors applied, bituminous material use and application rates are in accordance with present Montana State Highway Department practice. The unit cost used for surfacing was $2,579 per station on Alternates 1, 1-3 and 1-4; and $2,155 per station on all other alternates.

The structure costs shown in the summary "Construction Cost Estimates of Alternates Studied" were based on unit square foot costs of $10.50 per square foot for prestressed concrete girder construction. However, the structure on Alternate 5 is considerably higher than the average structure and a more comprehensive study showed that a unit cost of $17.00 per square

foot was more realistic. Details of this structure are shown in the section entitled "Major Structures." Each of these estimates contain a contingency factor of 10%. This is standard practice for structure estimates of a preliminary nature. Culvert lengths of pipes over 60 inches were determined from the cross-sections of the proposed roadway embankment at the point of crossing. Unit per foot prices of these pipes were taken from the average low bid prices of 1963 and 1964 Montana State Highway bids. Smaller pipes were estimated at a straight $15,000 per mile.

Guard rail is figured on all embankment slopes over 10 feet in height. The unit price used was $2.50 per foot. Type C. W. Standard Interstate Fencing was computed on the center line length for two sides continuous at $8.00 per rod. Access costs and right of way costs are discussed in other sections of this report and are listed as lump sum items in the summary under the heading "Right of Way." Clearing and grubbing areas were scaled from the aerial photos and computed at $750 per acre.

MISCELLANEOUS CONSIDERATIONS

Maintenance of Traffic

The cost to the highway contractor for maintaining passage and detours through the area under construction is a very real expense. It will appear in construction bids as a maintenance of traffic item, if used, or else be reflected in higher unit bid prices and is directly related to the distance involved.

For this project the cost of maintenance of traffic was considered great enough to bear consideration. The cost used was that computed from previous reconnaissance studies wherein an estimated shutdown time for the contractor was allowed during the time that vehicle passage was allowed. This time was used to charge rental costs for the equipment estimated to be used and for wages that would accrue. The unit cost used is five cents per cubic yard for the excavation volume involved at the location of interference. This item is listed in the summary of construction costs.

There are two areas where the interference would be significant. The most important area would be at the top of Boulder Hill where a deep excavation below the present crest will be required. The other would be on the connection from Alternate 5 to Alternates 7 and 8.

The counterpart of the expense discussed above is the additional vehicle operation cost to the road user from traveling on roads under construction. This too is a very real expense but is often considered as somewhat more intangible, since it will never appear in the bids for the construction work. A precise computation and comparison for this item is difficult due to the unpredictability of the extent of time required. It will be related to the contract time allowed for project construction but under this upper time limit, variance will occur according to the different methods of handling the project by different contractors.

This higher operating cost per mile considers stops, longer travel time, more vehicle and tire wear and lower gear operation, among other items. This expense is not incorporated into the construction cost summary or the road user benefit analysis, but should be considered in location selection when it is of large magnitude. The following table shows the estimated costs for one year to the road users by travel on a detour type roadway as compared to the Interstate, and the costs accrued through delay while blasting and related operations are performed.

Alternate	Cost Due to Detour	Cost Due to Delay	Total Cost
3	$12,662	$61,800	$74,462
4	9,518	55,620	65,138
5	3,857	18,540	22,397
6	7,830	37,080	44,910

The expense for detours is computed by multiplying the difference between the present road users cost per mile and the road users cost on a detour type roadway per mile (3.14¢), times the number of affected miles (variable with each alternate) and the daily 1968 ADT (1545). For this comparison it is assumed that all portions involving interruption of normal traffic operation for any one alternate would be under construction simultaneously.

The expense for delay was computed by multiplying the hourly delay cost ($1.60) times the average expected delay (15 min.) times the 1968 ADT (1545) times the estimated construction period. ($1\frac{1}{2}$ months to 12 months, relating to the rock construction necessary where confliction with traffic will occur).

Since either Alternate 3 or 4 and Alternate 5 or 6 must be constructed it can be seen that the difference between them is not a very significant amount.

Interchanges

Access to and from the Interstate was considered at several locations. Where access was considered the cost of an interchange was also considered. No locations were deemed feasible for an expenditure for off and on ramps. A structure over Alternate 1 or 2 was found to be a necessary item. These are discussed under the item "Access." Ramps could be added to this structure at some future time if area development expansion would require it.

Utilities Adjustments

On all alternates except Alternate 1 there will be utilities whose locations are coincident with the proposed Interstate Highway. On Alternates 3 and 4 the location confliction occurs with a telephone line. The other conflictions are with the Montana Power Company's 6 inch natural gas main and the double pole 69,000 volt power line. The gas line and the power line are side by side through the project.

Location of the alternates was made with the relocation costs in mind. The telephone relocation is estimated at a cost of $200 per pole. The Montana Power Company's 6 inch gas line is estimated to cost $6 per lineal foot for relocation; the 69,000 volt power line $350 per pole.

Winter Maintenance Procedures

It is recognized that current maintenance procedures of sanding from the top of the hill both ways can no longer be followed. If they were, the sanding truck would be travelling against two lanes of traffic on a four lane highway in adverse conditions. However, the sanding trucks are currently designed to sand in high gear since it is in this gear that the power take-off spreads the right amount of sand and this requires downhill operation.

In order to maintain the new Interstate properly the trucks will have to be revised in such a manner that they can spread sand in a lower gear. They will have to sand from the bottom of one side of the hill to the bottom of the other side in one direction for each pair of lanes. Current practice requires a truck load of sand for each side of the hill. Because the new highway will have about twice the surfacing area, it is expected that four truck loads of sand will now be necessary. Since the truck is allowed to go only in one direction, it will arrive at the top of the hill empty. If sand is not available here, it must proceed to the next sand bin and return to finish the sanding of the downhill side on another trip.

Several solutions are possible to reduce the time and cost of this sanding procedure. First, it has been indicated by the Montana Highway Department that the maintenance house presently near the top of the hill, will be moved to Jefferson City. With regard to the sanding of the hill, this will allow a truck to start southbound up the hill sanding along the way, assuming of course, that sand is available at the new maintenance house location. When the truck reaches the top of the hill it will be out of sand. However, if sand is available at the rest area, it can load again and continue. When it reaches the bottom of the hill on the Boulder side it will again be out of sand. It will be necessary to get sand here and turn around to sand uphill toward Jefferson City. To perform this operation, several ways are possible. A simple median cross-over between lanes is hazardous and provides no way to pick up sand. A "jug-handle" turn-around arrangement with the sand supply at the

outside of the handle would serve quite well. However, there is the hazardous right angle crossing that must be made by the sanding trucks.

Because there is a structure proposed at the bottom of the hill to provide access across the Interstate at this point, maintenance ramps could be constructed on the north side of the structure to provide access off southbound and access on northbound. This would serve to safely allow trucks to turn around and to pickup sand at a location away from the Interstate. These ramps could be constructed at a cost nearly the same as a jug-handle turn around. The ramps could be constructed to the same standard as the turn around. A sand loading depot can easily be constructed at the end of the ramp at a point of easy construction.

After the truck has made the turn around it can sand northward up the hill. It will pick up sand at the other rest area and complete the sanding of the hill to Jefferson City.

It is recommended that sand loading facilities be constructed at the recommended rest areas and ramps be constructed as well as sand loading facilities at the structure at the bottom of the hill on the south side. A sand depot will have to be constructed at Jefferson City. If the maintenance station is moved to this location, the depot can be conveniently constructed there.

Considerations For A 2-Lane Section

It is evident from the profile grades and the existing ground lines shown in the Plan-Profile drawings that there are two distinct topographic areas within the project limits. The southerly 4 miles of the project traverse the flat bottom of the Boulder Valley. The

remaining seven miles are through a distinctly more hilly country.

A four lane facility is recommended throughout the length of this project and is the basis used for all material in this report.

It is evident that four lanes should be designed and constructed on the northerly seven miles of the project due to the curvature of the drainage valleys and the summit elevation of Boulder Hill. On any alignment, over two miles of five per cent ascending grade is required on each side of Boulder Hill even with a deep excavation at the crest of the hill. The configuration of the sidehills makes extensive horizontal curvature of the alignment necessary.

The need for four lanes through the bottom of Boulder Valley when this section is considered by itself cannot be justified on the basis of alignment restrictions and resultant vehicle capacity reductions below the predicted design year traffic volumes. However, it can be and is strongly recommended that four lanes be constructed in this area also. This can best be supported on the basis of the desirability of maintaining continuity of a four lane facility.

There are several reasons for constructing this section with four lanes.

1. In all probability the Interstate planned from Boulder towards Butte, whether it is decided to follow the present U.S. 91 location or a new location up the Little Boulder River, will require a four lane facility due to natural topographic restrictions.
2. An interchange will be required at the city of Boulder. This

interchange will have a high traffic count and it is highly desirable for safety to the highway users that four lanes be carried through this Interchange. Good design provides that logical continuity of the four lanes be preserved on the Boulder to Butte Interstate.

3. With 4 lanes beyond Boulder and a four lane interchange in Boulder and four lanes over Boulder Hill itself the short four mile extent across Boulder Valley becomes the subject for justification. If this section were to be two lanes, two transitions would be required. Proper design would dictate the use of a minimum of a quarter of a mile for each transition length. The two combined would thus reduce the effective length of 2 lanes by one-half mile to a three and one-half mile section. It would not seem to be sound judgement to inject such a short section of relatively hazardous 2-lane highway into this area for what would be short sighted economy.

4. Hazard is introduced with a short two lane section due to a change from a facility which provides full freedom of operation to one with a restricted condition. Immeasurable safety is provided by dual lanes in each direction on a four lane highway from the standpoint of ability for traffic traveling in the same direction to overtake and pass other vehicles, regardless of the available sight distance, with full knowledge that the hazard of closely encountering oncoming traffic has been eliminated. It reduces tensions that are associated with passing

The passing of trucks can be accomplished with very little effort in modern cars by most drivers on wide paved two lane highways where sight distances are adequate. However, most drivers have also experienced the conditions of uncertainty and the feelings of hesitancy created when following a truck and preparing for a passing maneuver under adverse weather conditions. This would be true during snow or rain or just with the roadway wet from thawing snow or ice. The usual result is a turbulent cloud of snow or water mist surrounding and trailing the rear of the truck, trailer, or bus. The consequent situation is usually one where the driver of the trailing car is unable to view the necessary span of roadway ahead, even though there may be straight alignment with no sight restrictions to prevent passing. The prudent driver should not pass under these circumstances. Human nature being what it is, however, will cause many drivers to take chances under adverse situations.

The elimination or minimization of hazards should continually be striven for as one desirable goal of improved highway design. The foregoing particular example cited is one that can be overcome through the use of the proposed four lanes.

5. Hazard is also introduced from the standpoint of the necessity of the driver to change his attitude to adopt from the free movements on a four lane to the restricted movements on the two lanes. The transition area from two lanes to four can be

a trouble area even when well designed. The three or four minutes in which a two lane section could be traversed is a very short time for the drivers to adapt and readapt. This tends to maximize the potential hazards created by careless and even the average driver.

This does not mean that the highway could be considered as designed for only the careless driver because even the most careful driver may be directly affected by the actions of the careless driver.

6. It is recognized that the cost of four lanes is higher than that of two lanes, but much more facility value is obtained for the additional cost. It might be considered as part of the cost for providing safety. The open straight areas are the cheapest per mile that can be obtained.

Based upon the foregoing information it is considered and recommended as necessary that four lanes be constructed across the Boulder Valley. This will comply with the basic concepts of safety of the Interstate Highway System which are to be applied to every mile of Interstate Highway and not only to the high traffic volume areas.

Terrain - Design Relationship

The terrain for design purposes has been classified as flat and rolling. This is for the purpose of establishing maximum limits for the geometric design standards of the locations studied.

Since a precise definition of terrain types has not been established by A.A.S.H.O., another information source should be examined. One that is available is that used by the Arizona Highway Department. It defines the group of terrain types as follows:

Flat Topography:	Cuts and fills up to 10 feet are common. Grades of 3 per cent or less can be obtained without affecting alignment appreciably.
Rolling Topography:	Cuts and fills up to 80 feet are called for. Short runs of maximum grades.
Mountainous Topography:	Terrain with precipitous canyons and escarpments. Extended maximum grades required.

Using these definitions as a guide, it is reasonable to use the classifications of flat topography for the location across Boulder Valley. Similarly the basic designation of the remainder should be rolling topography rather than mountainous topography. However, it will not strictly fulfill one classification only.

With the realization that the terrain is more severe than is implied by the rolling topography classification, some moderation of the limiting geometric features have been used. These include the use of long sustained 5% ascending grades and long sustained 6% descending grades. Maximum allowable sharpness of curvature should not be combined with these steep grades. For this reason horizontal curves have been kept under 5 degrees.

RECOMMENDATIONS

The Recommended Alignment is comprised of Alternates 2, 4, 6 and 8. This Alignment has a lower annual cost than any other. There are four Alignments that have a lower initial cost than the Recommended Alignment. The lowest of these is Alignment 2, 3, 6, 8, which is $100,000 less cost than the Recommended Alignment. All four of these Alignments cost $50,000 more annually. The Recommended Alignment lacks 200 feet of being the shortest alignment.

The Recommended Alignment was exhibited at a public hearing in Jefferson City on January 21, 1965. No objections were offered. Statements made during and after the hearing indicate that the Recommended Alignment provides better service to adjacent property owners than any other alignment.

It is also recommended that, for reasons set forth in this report, the Interstate Highway between Boulder and Jefferson City be a 4-lane highway. Lastly, it is recommended that the access roads and structure be constructed as set forth in the text, basing final locations on the results of the final design.

FIGURE 1

PLAN PROFILE LEGEND

PLAN DATA

SCALE: 1"= 400'

ALIGNMENT 2, 4, 6, 8

FRONTAGE ROADS,
ACCESS ROADS,
& REST AREAS

STRUCTURE

VEHICULAR UNDERPASS

D = DEGREE OF CURVATURE, SIMPLE CURVE
D_c = DEGREE OF CURVATURE, SPIRAL CURVE

CHANNEL CHANGE

PROFILE DATA

SCALE: HORIZONTAL 1"= 400' , VERTICAL 1"= 80'

NORTHBOUND
GROUND LINE

GRADE LINE

SOUTHBOUND
GROUND LINE

GRADE LINE

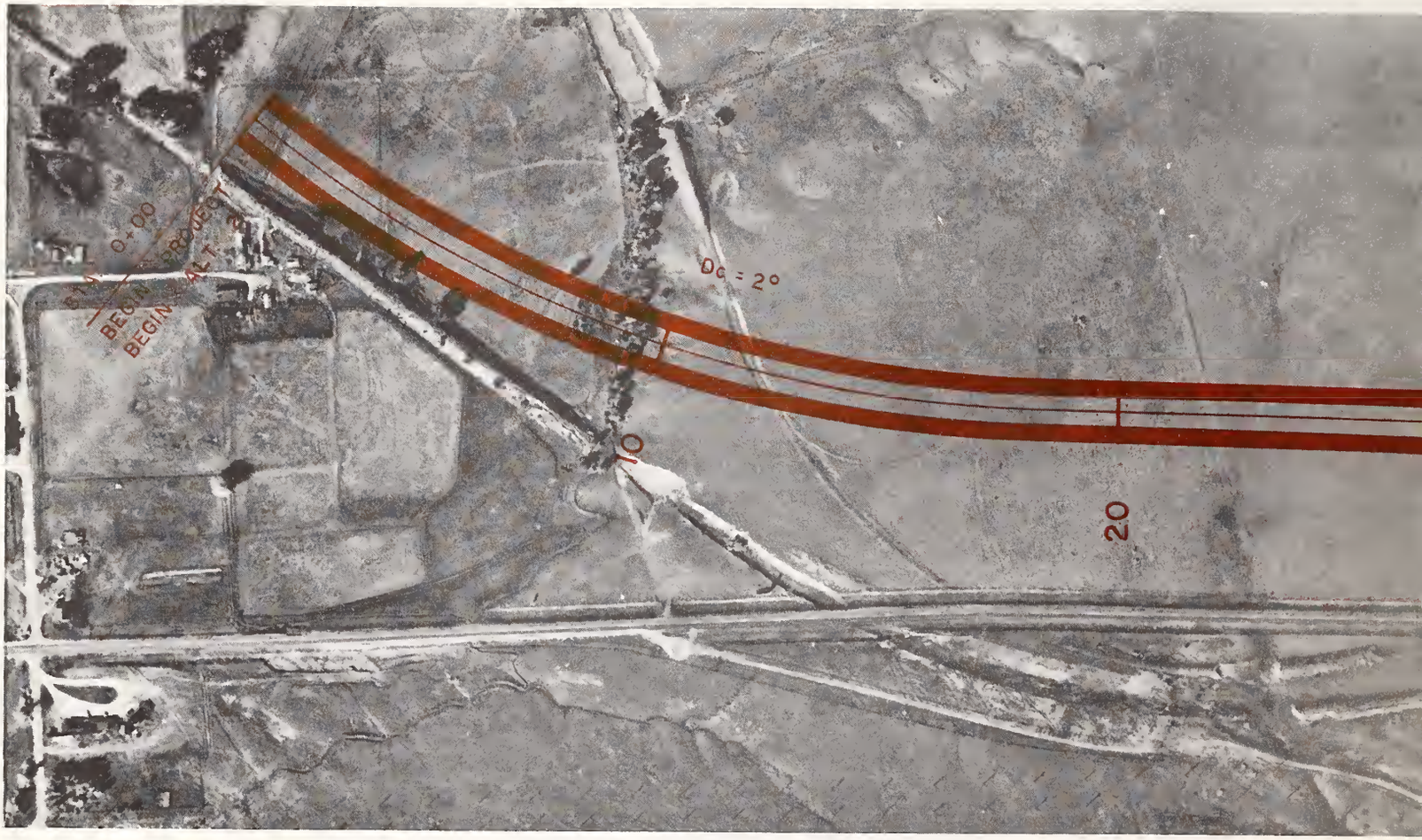
V. C. = VERTICAL CURVE

POINT OF CURVATURE TO POINT OF TANGENCY ON VERTICAL CURVE

NOTE

WHEN ONLY ONE GROUND & GRADE LINE IS SHOWN, PROFILE IS CENTER OF MEDIAN

FIGURE 2



ALTERNATE 2

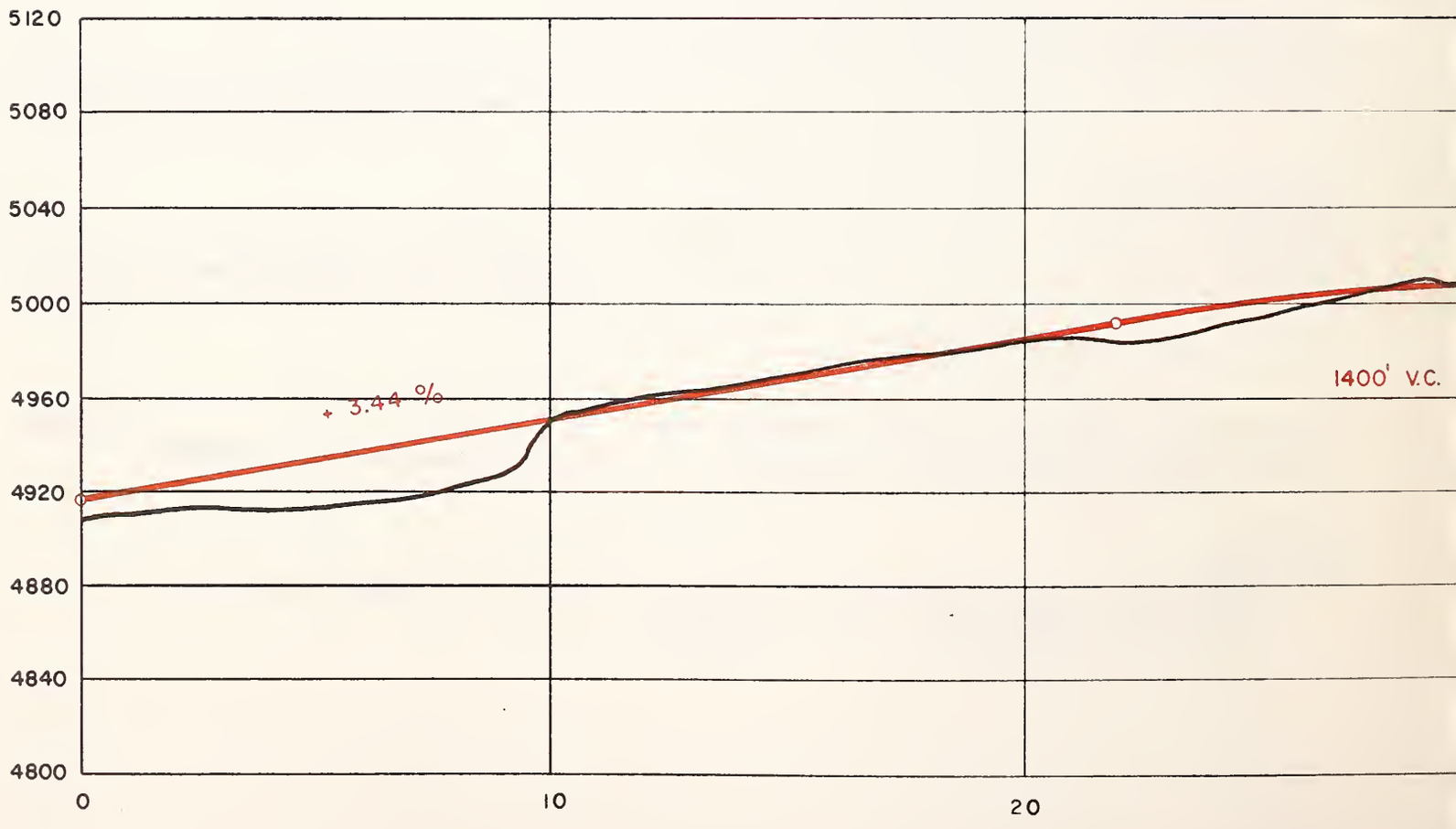
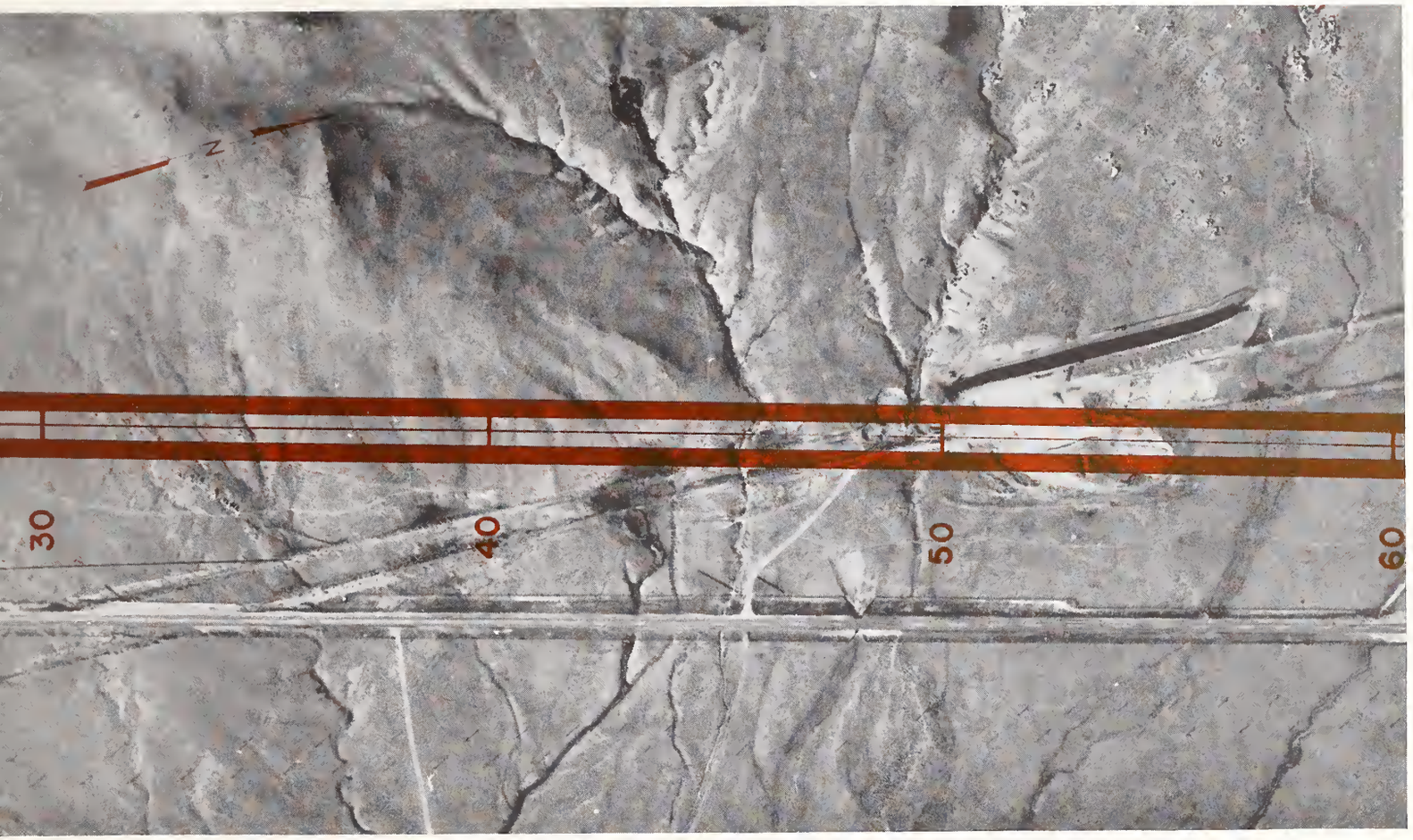


FIGURE 3



ALTERNATE 2

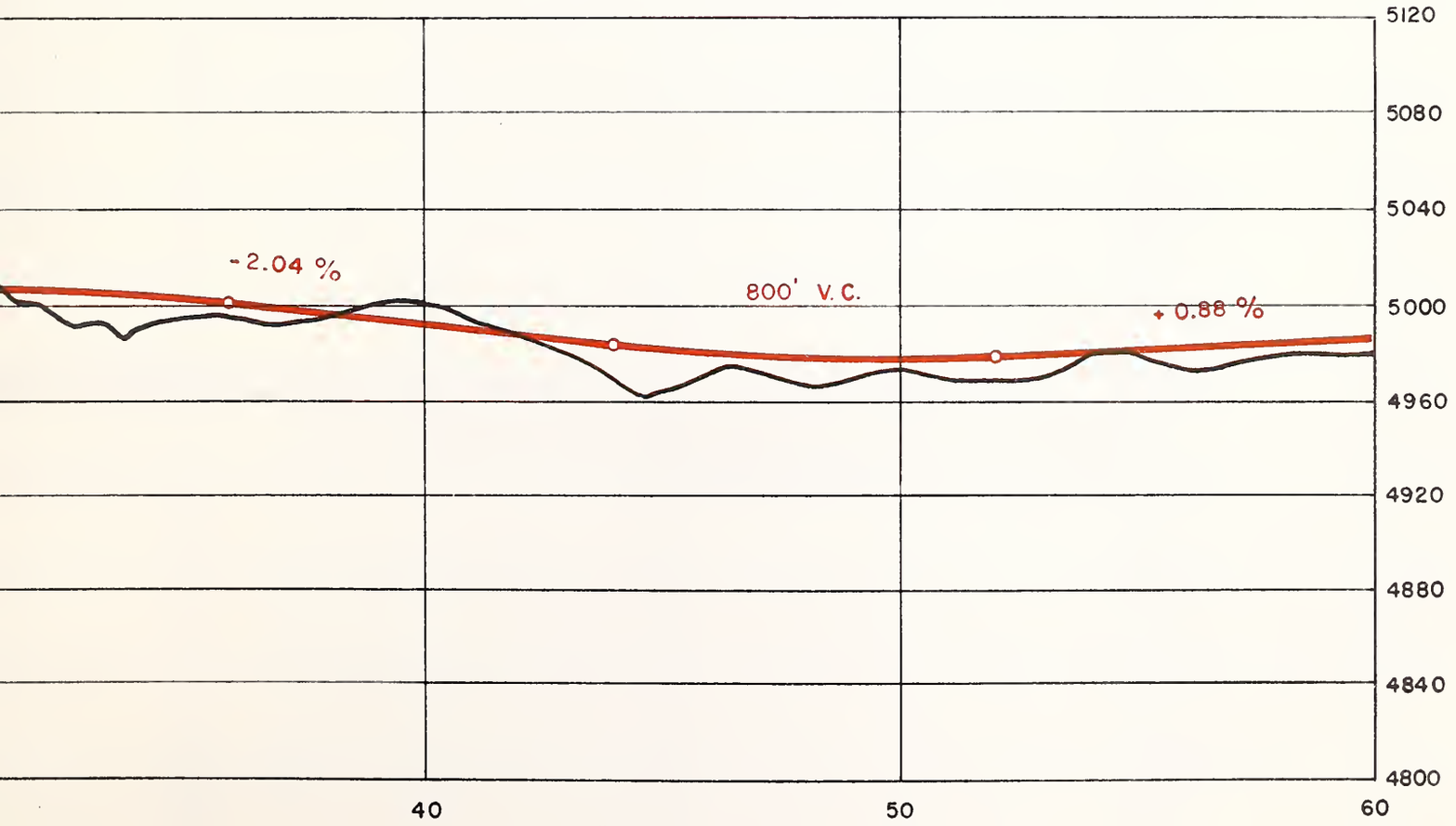
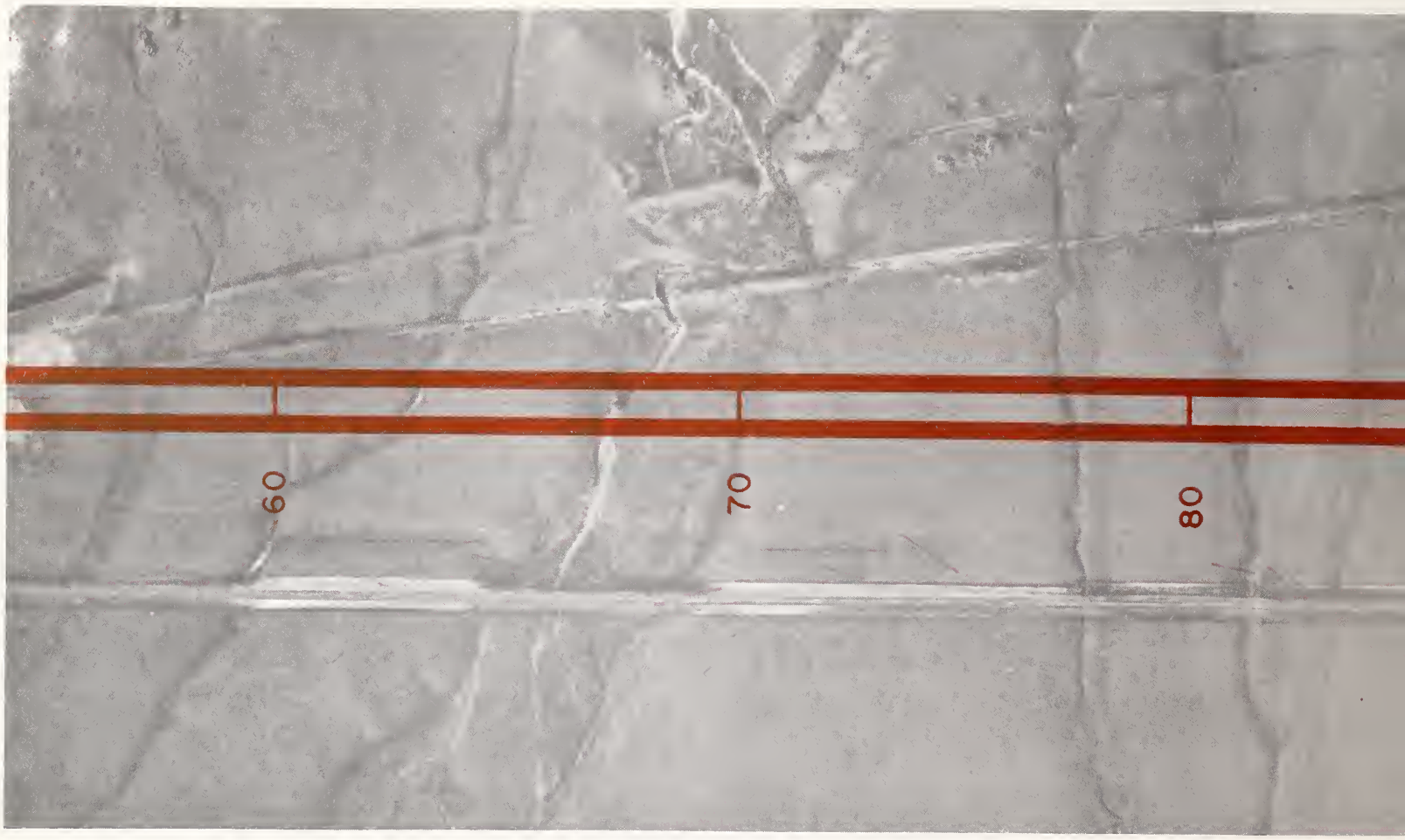
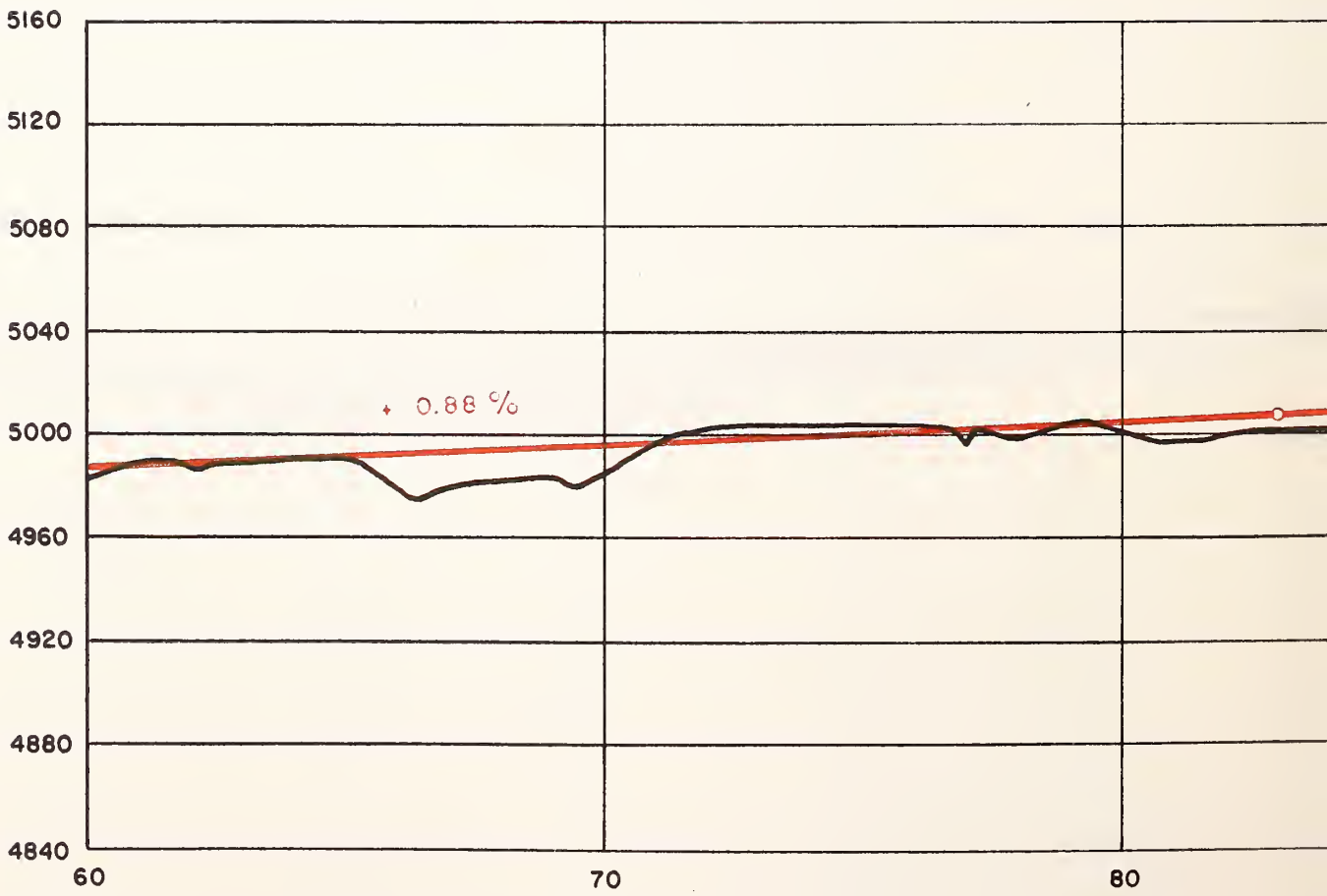


FIGURE 4



ALTERNATE 2



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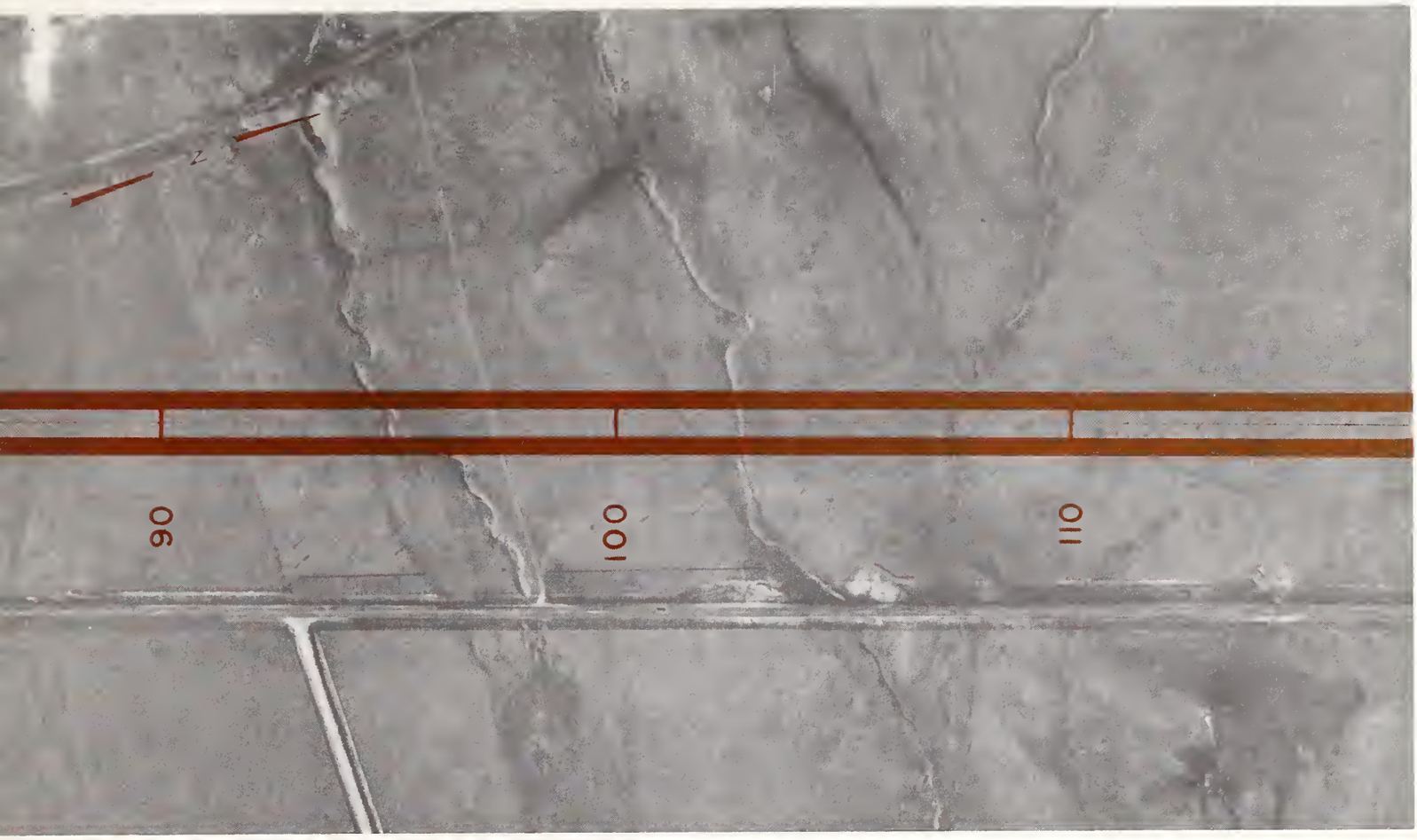
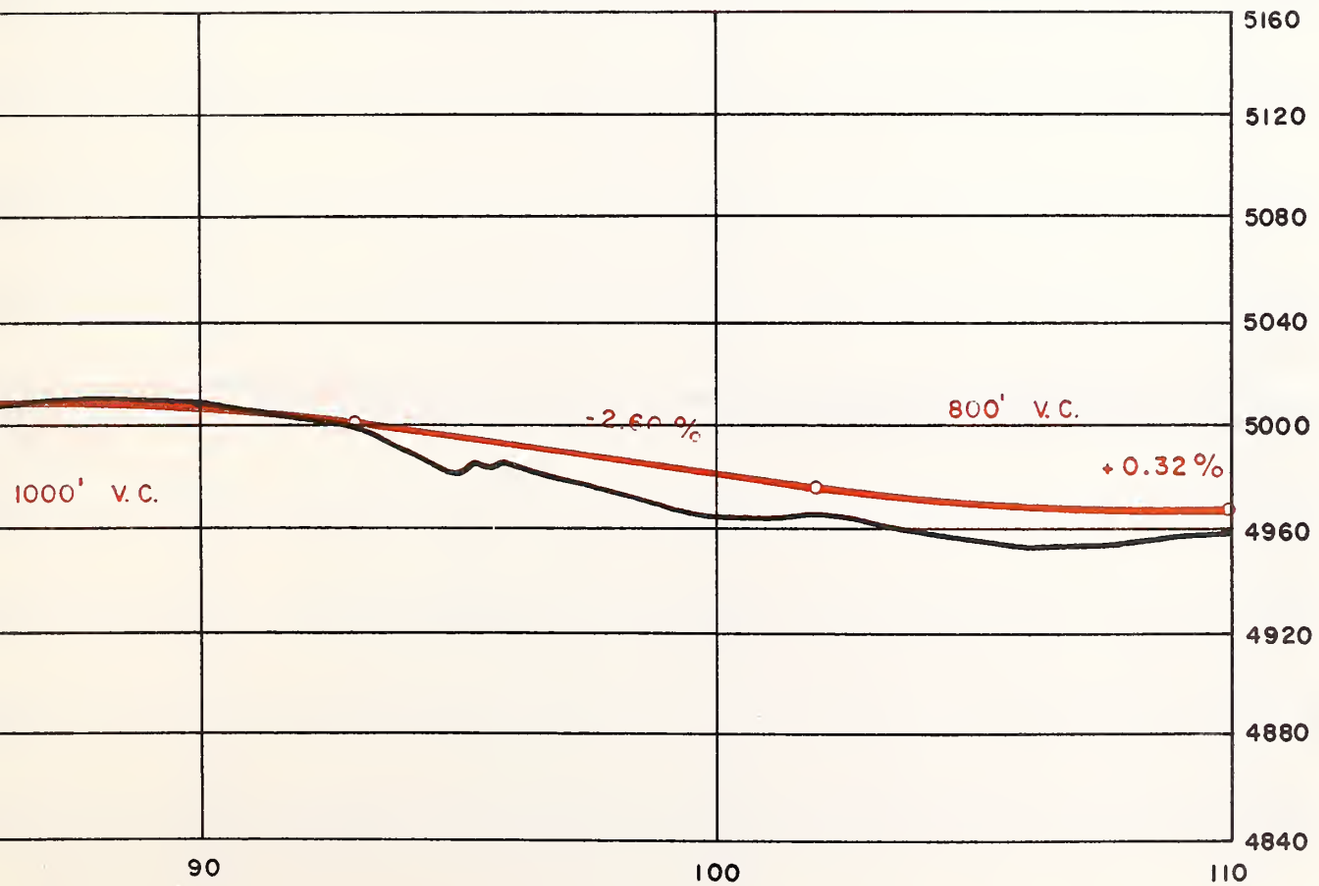


ALTERNATE 2



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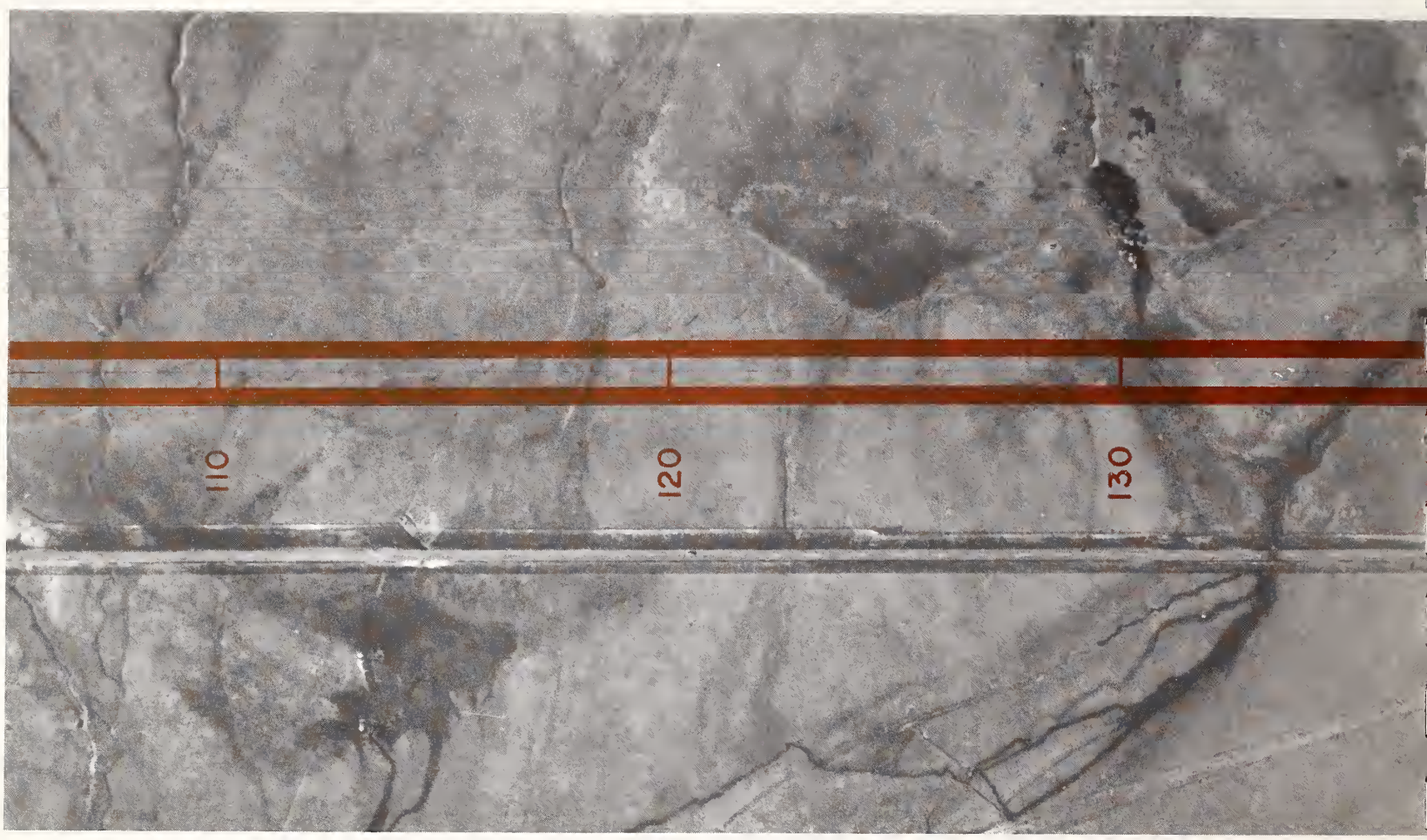
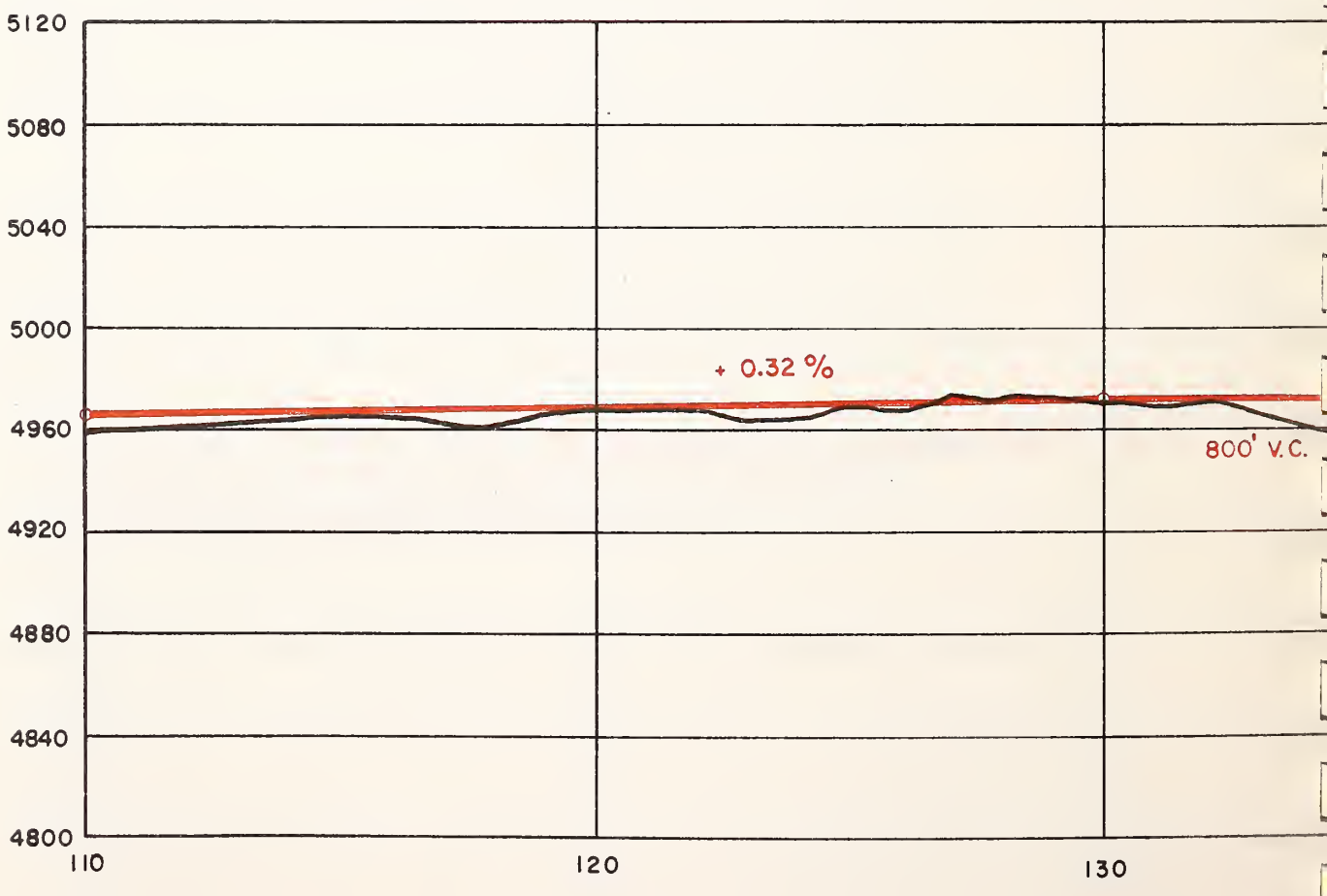
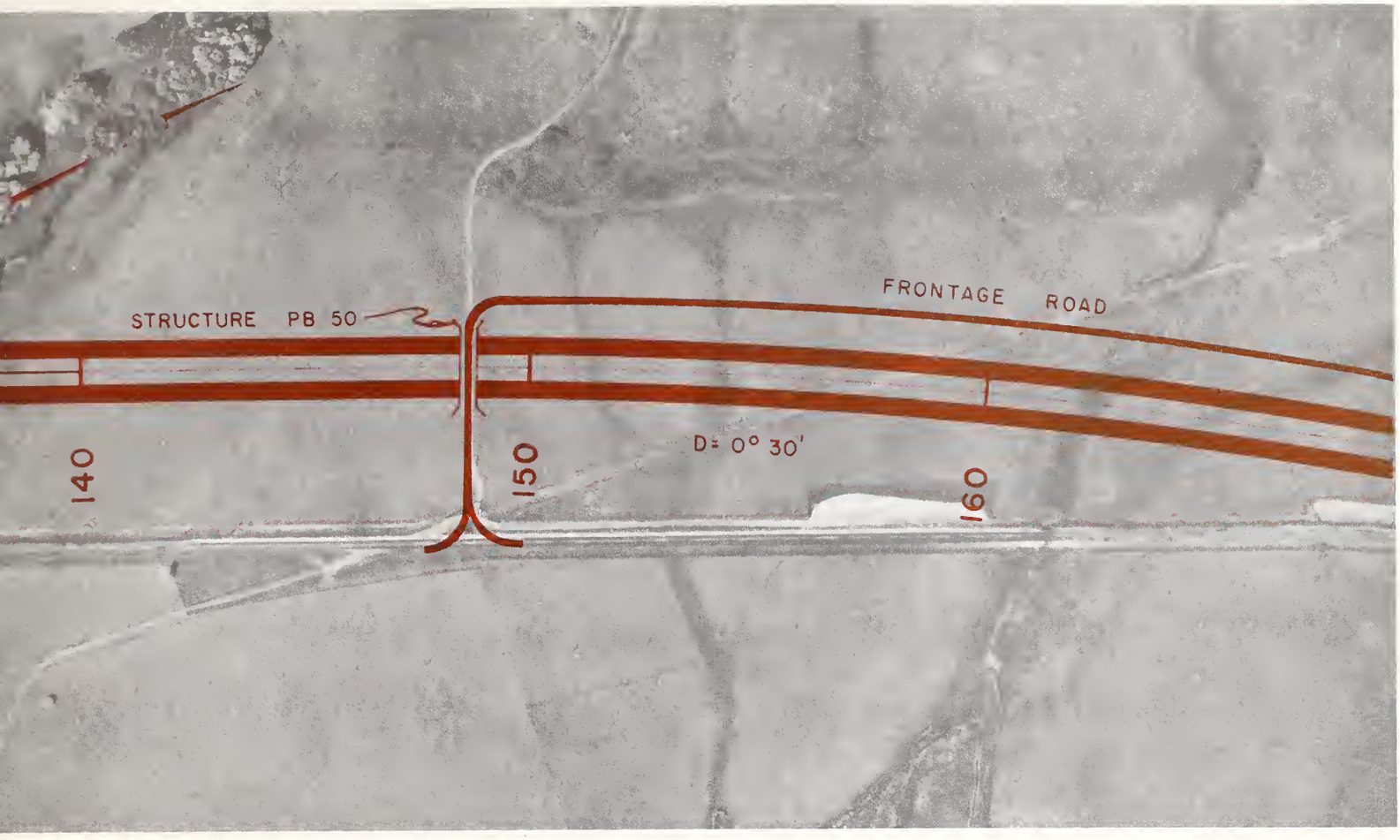


ALTERNATE 2




STRUCTURE PB 50
FRONTAGE ROAD
D= 0° 30'
140
150
160

ALTERNATE 2

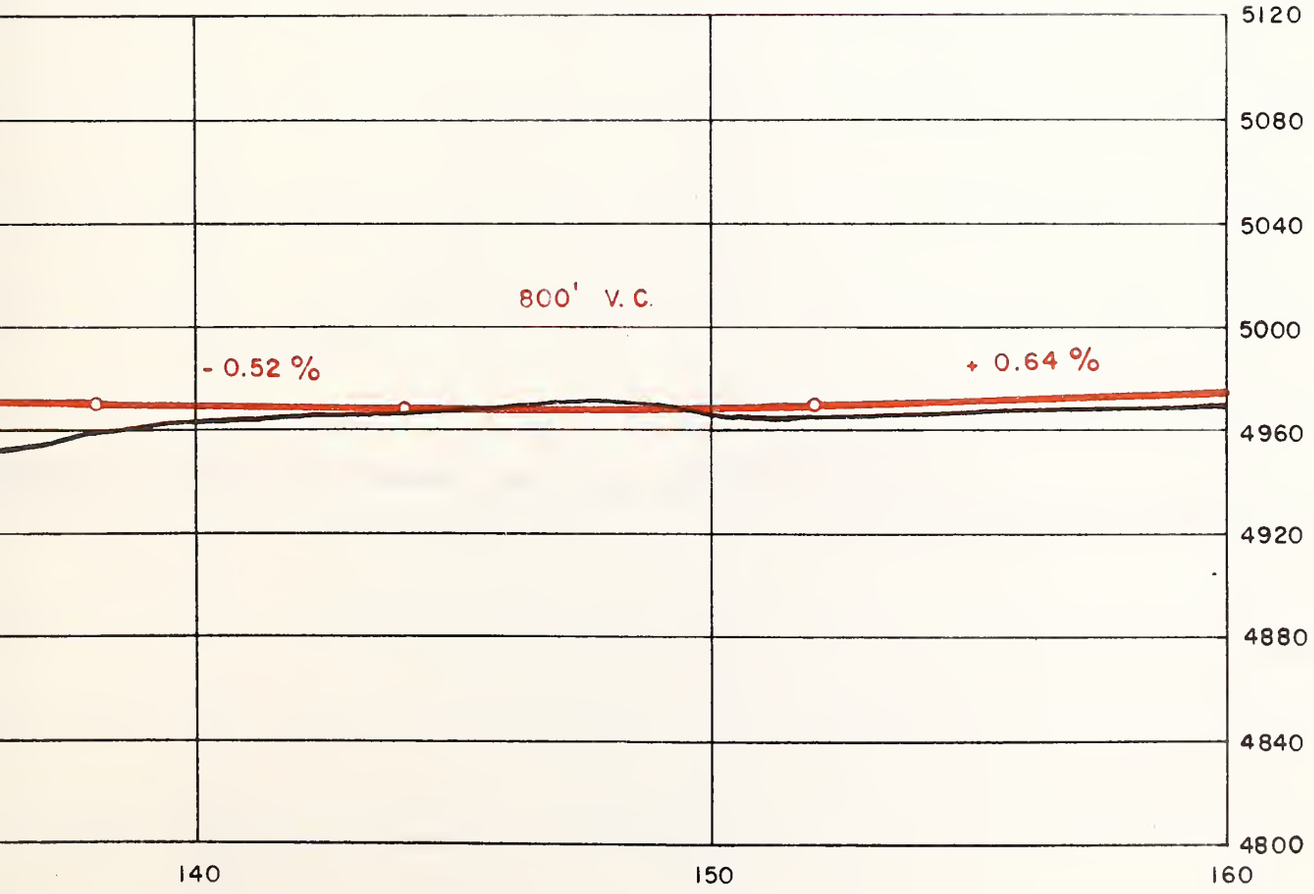
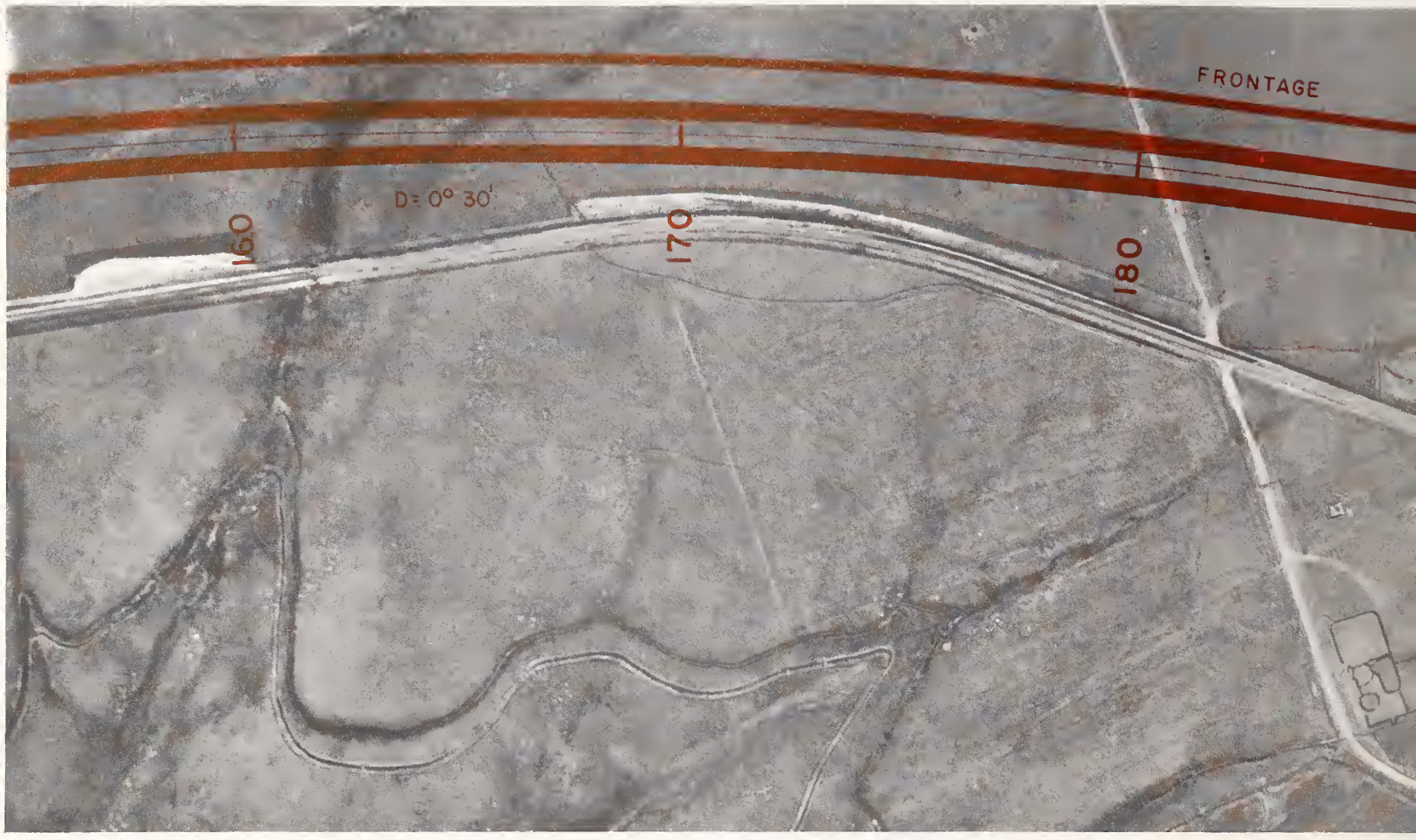
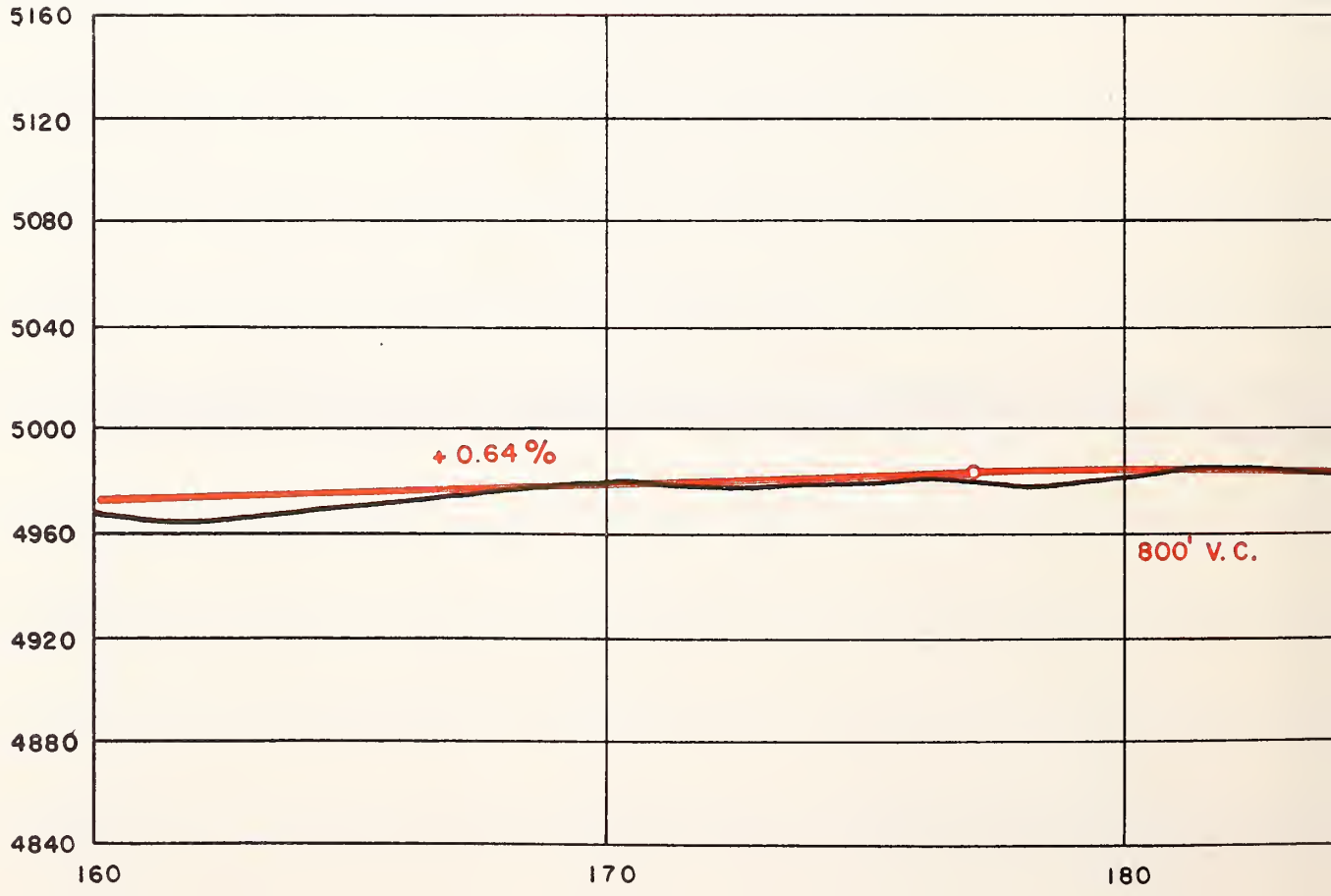
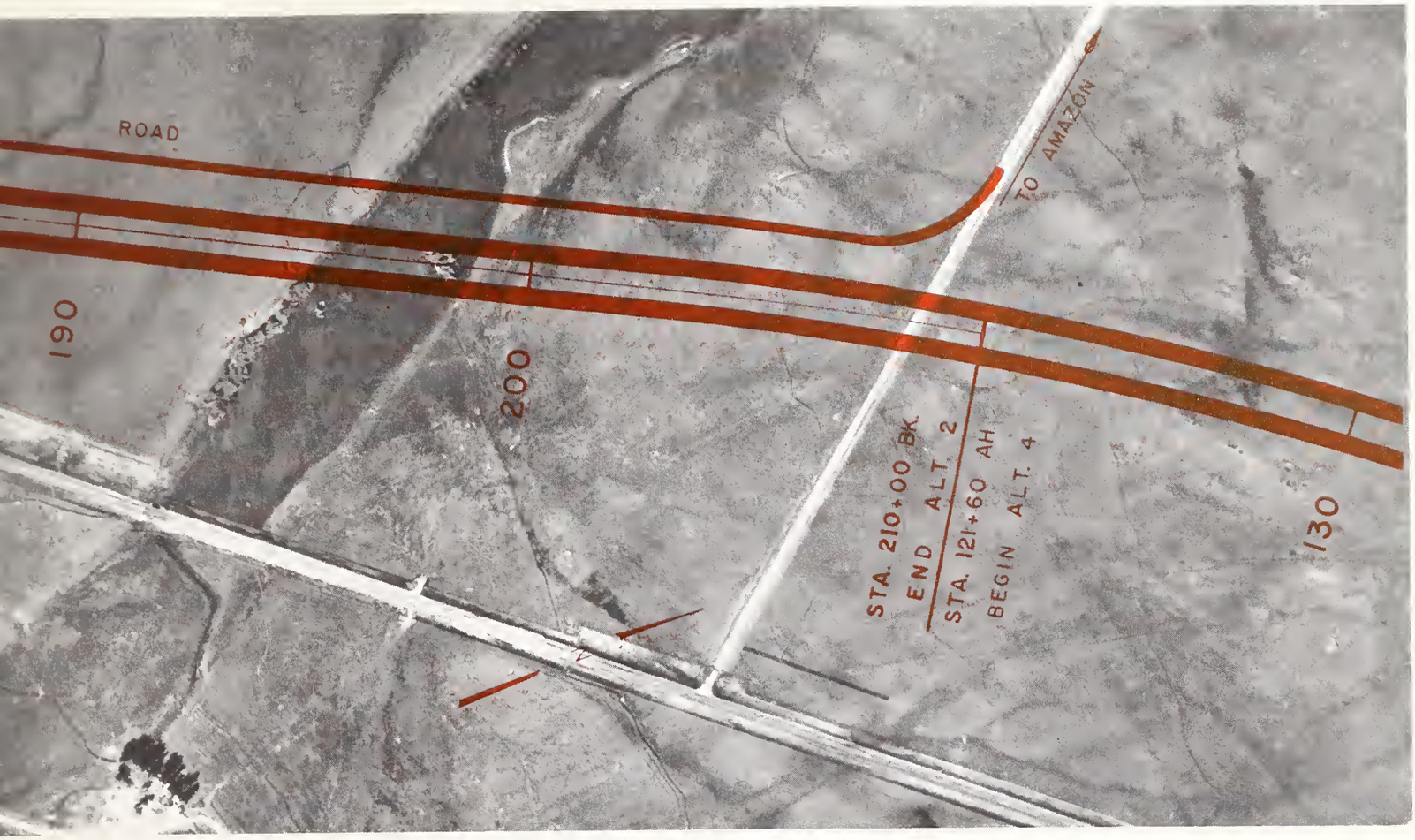

5120
5080
5040
5000
4960
4920
4880
4840
4800
800' V. C.
- 0.52 %
+ 0.64 %
140
150
160

FIGURE 8



ALTERNATE 2




ROAD
TO AMAZON
190
200
130
STA. 210+00 BK.
END ALT. 2
STA. 121+60 AH
BEGIN ALT. 4

ALTERNATE 2

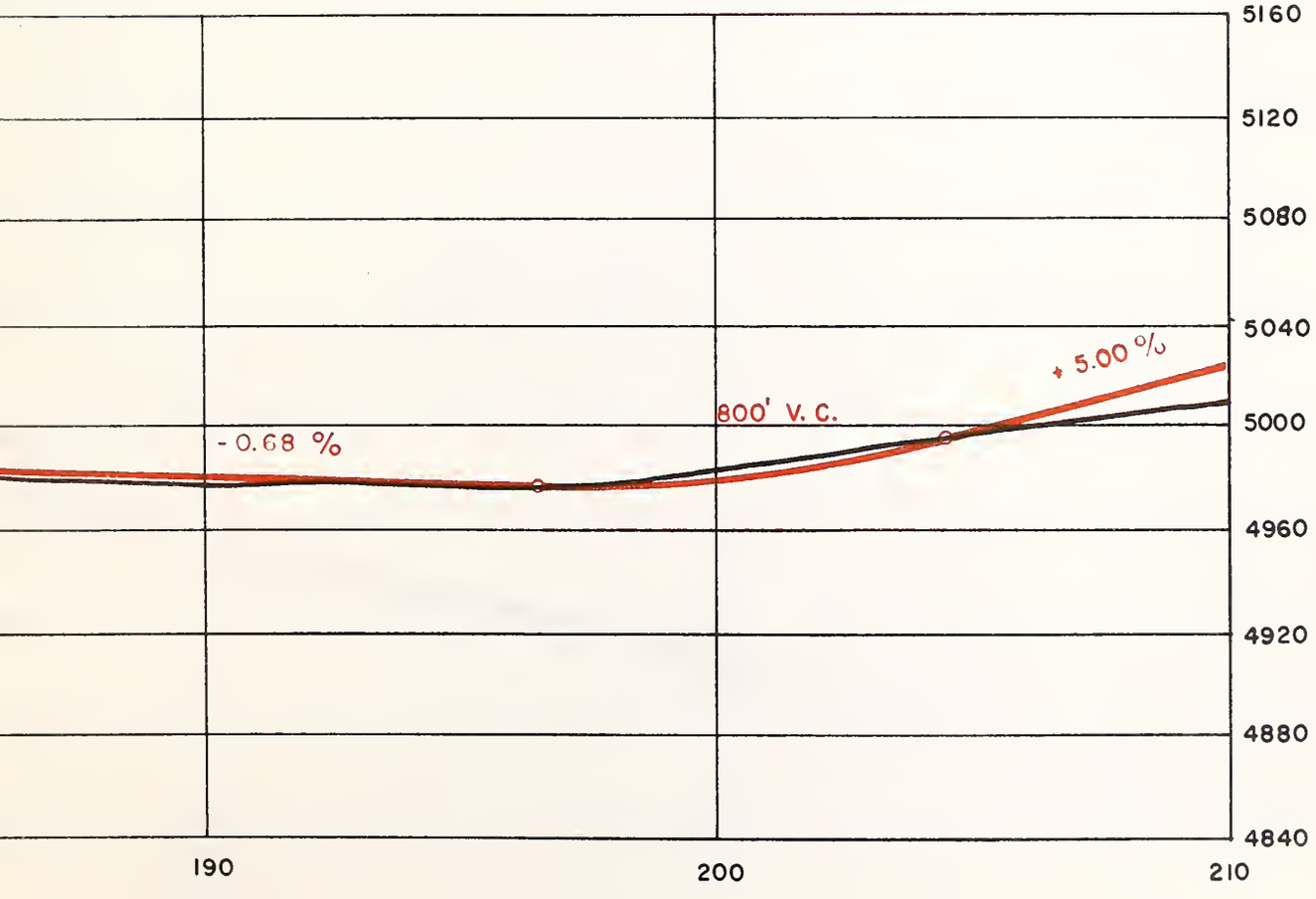
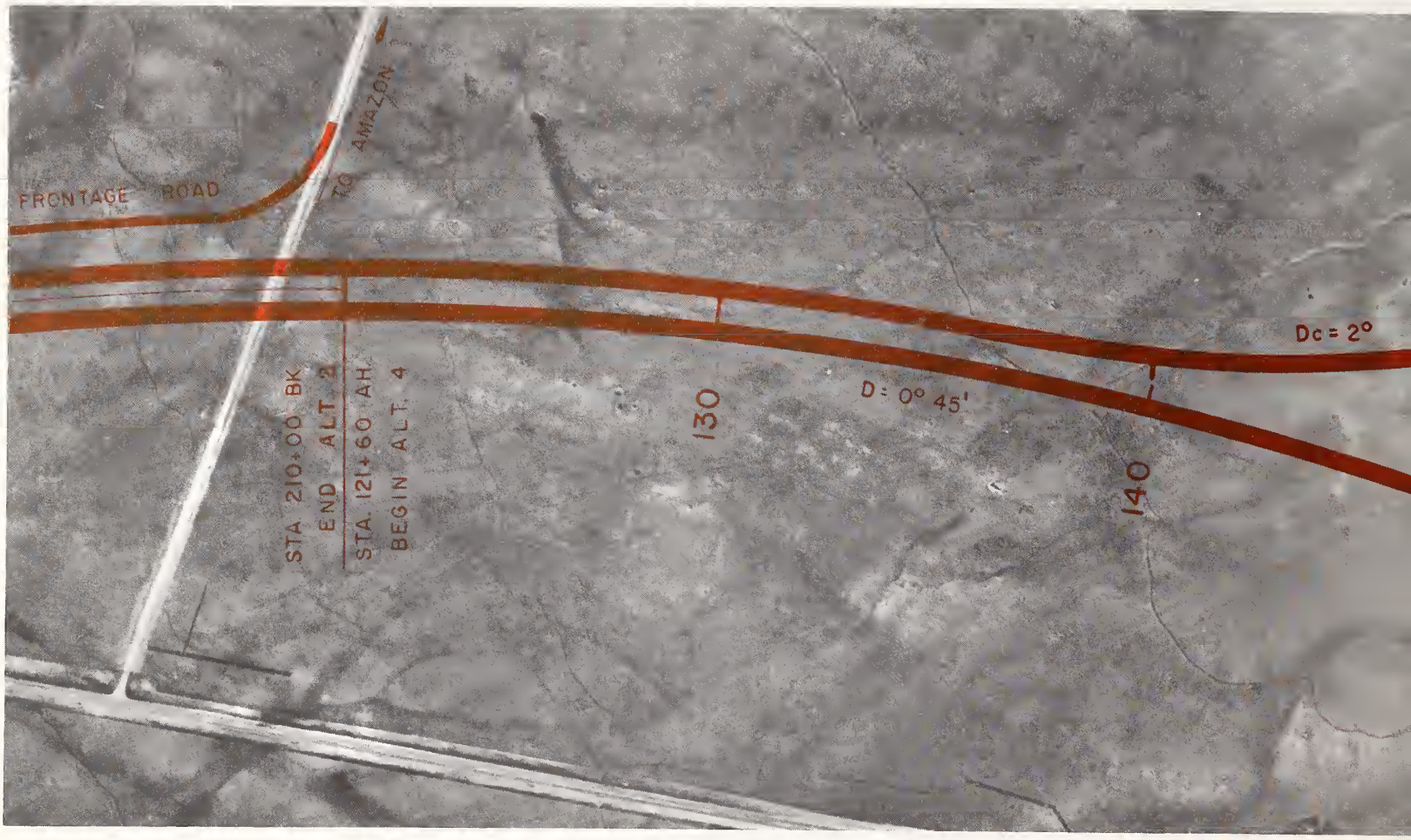

5160
5120
5080
5040
5000
4960
4920
4880
4840
+ 5.00 %
800' V. C.
- 0.68 %
190
200
210

FIGURE 10



ALTERNATE 4

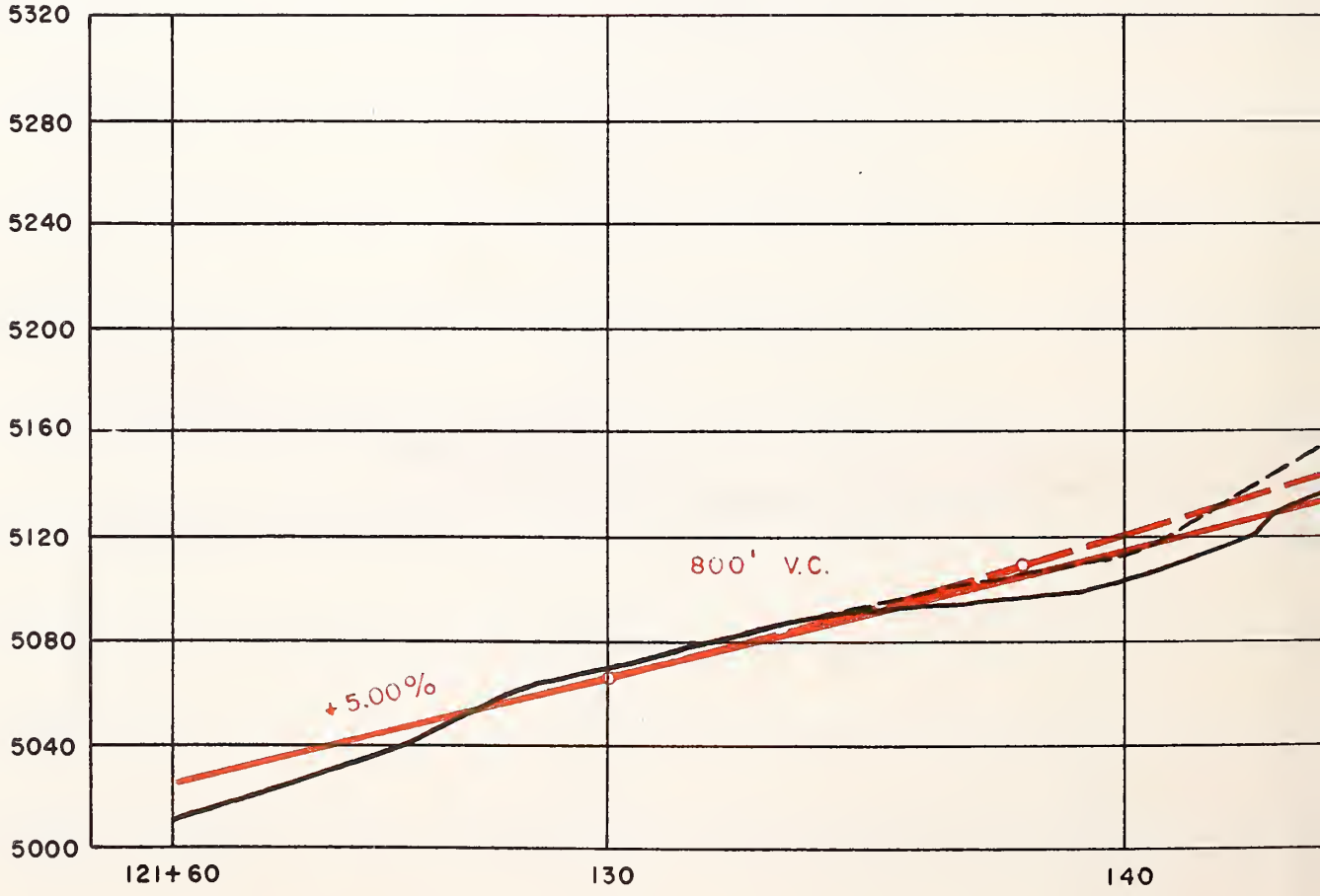
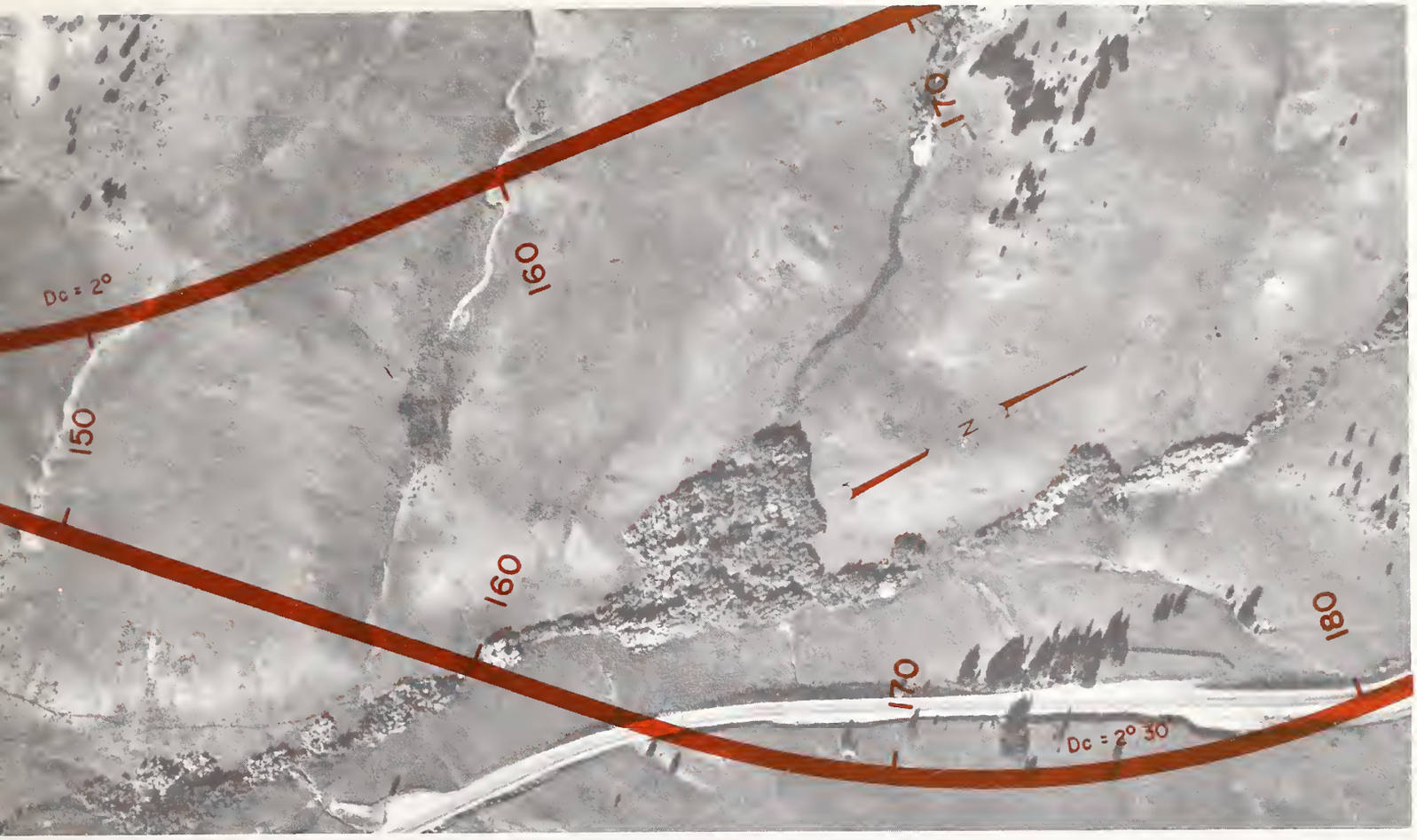


FIGURE 11



ALTERNATE 4

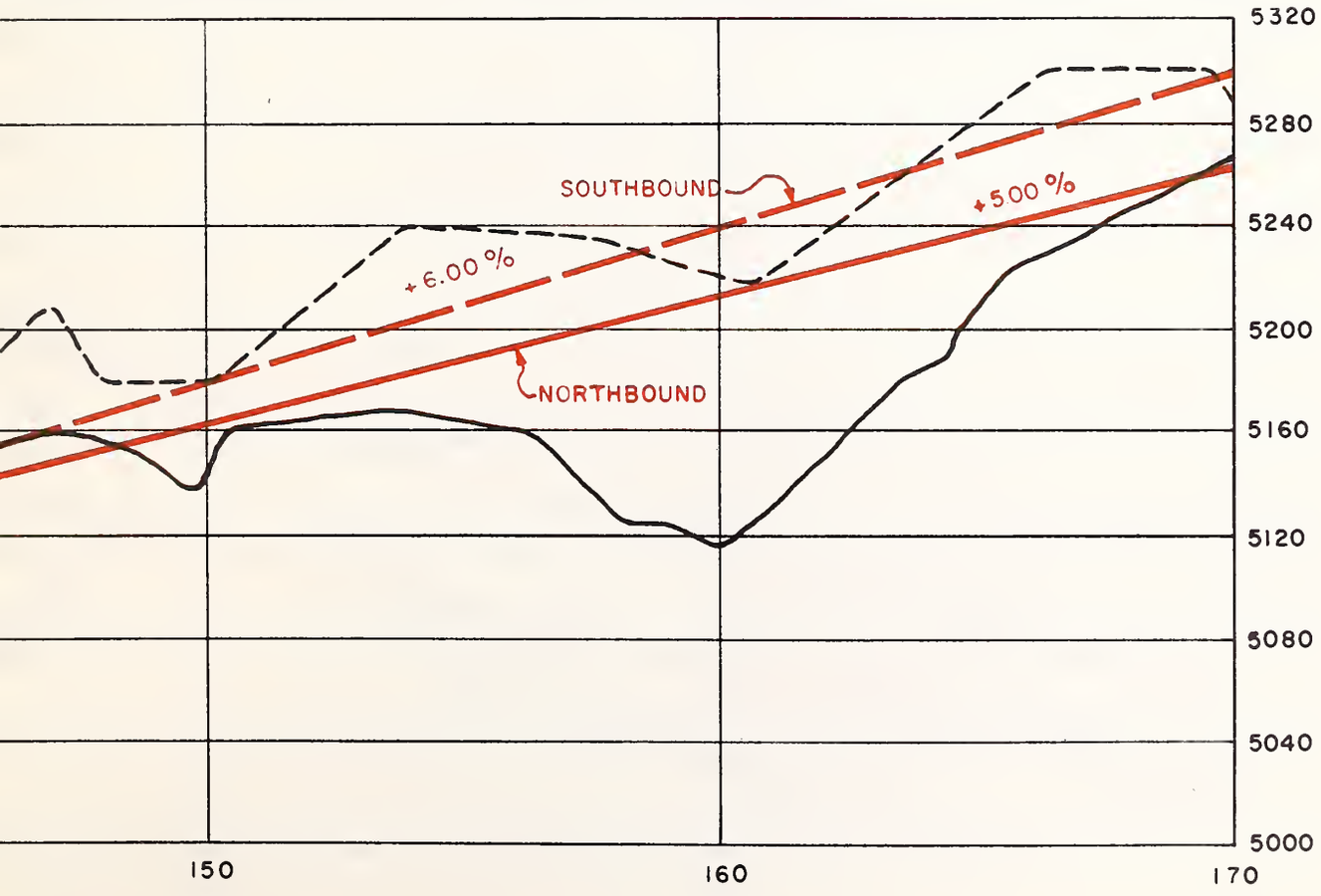
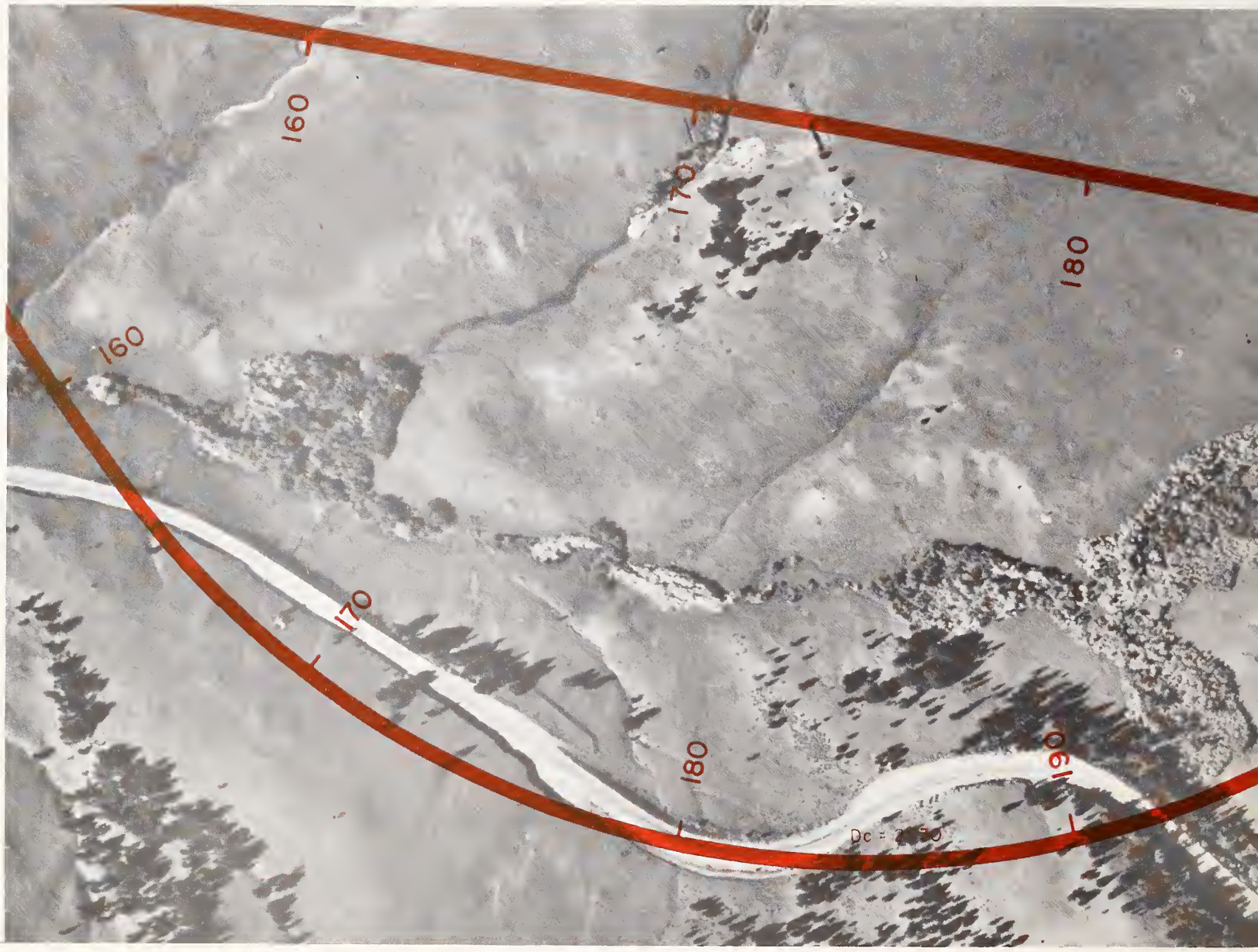


FIGURE 12



ALTERNATE 4

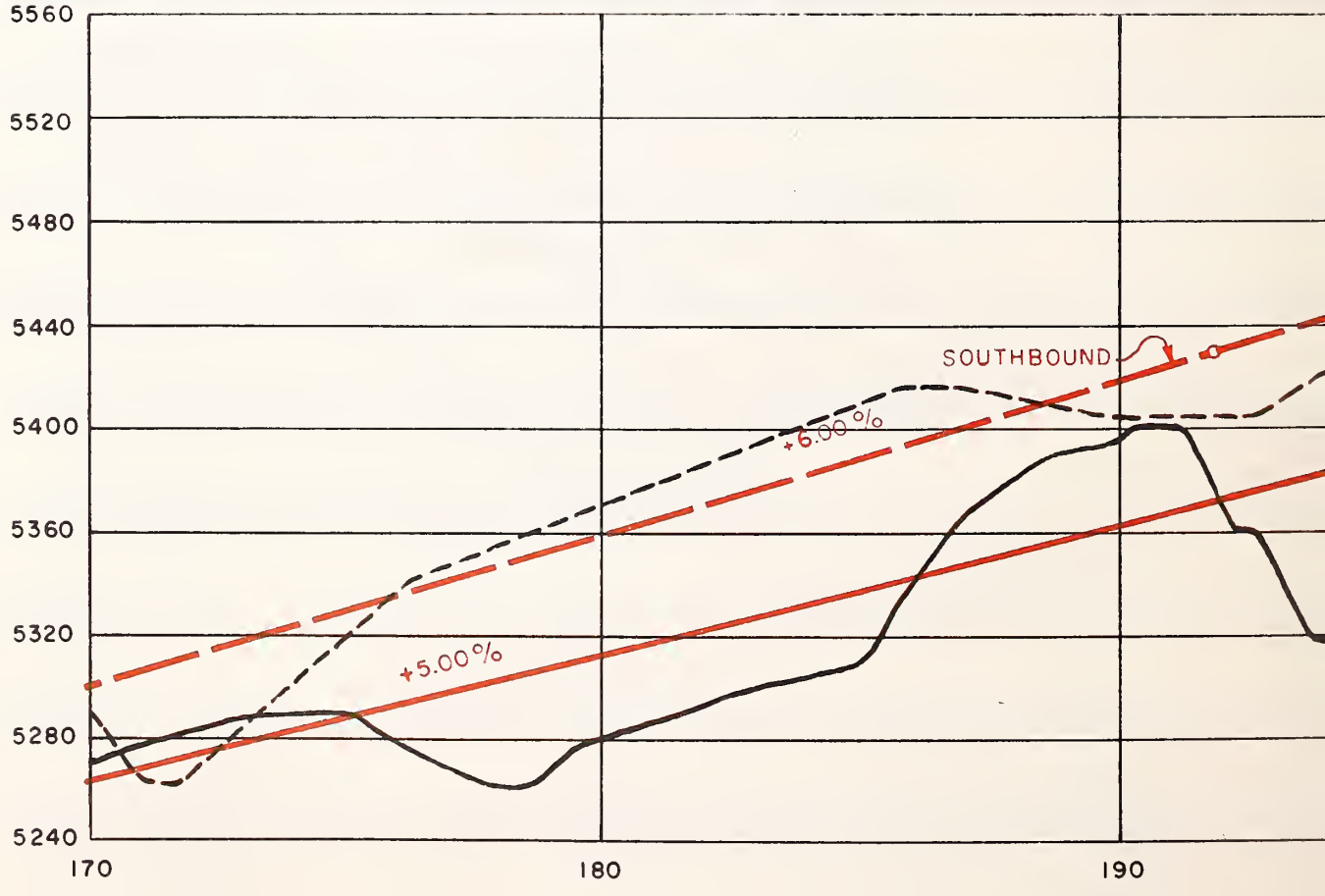
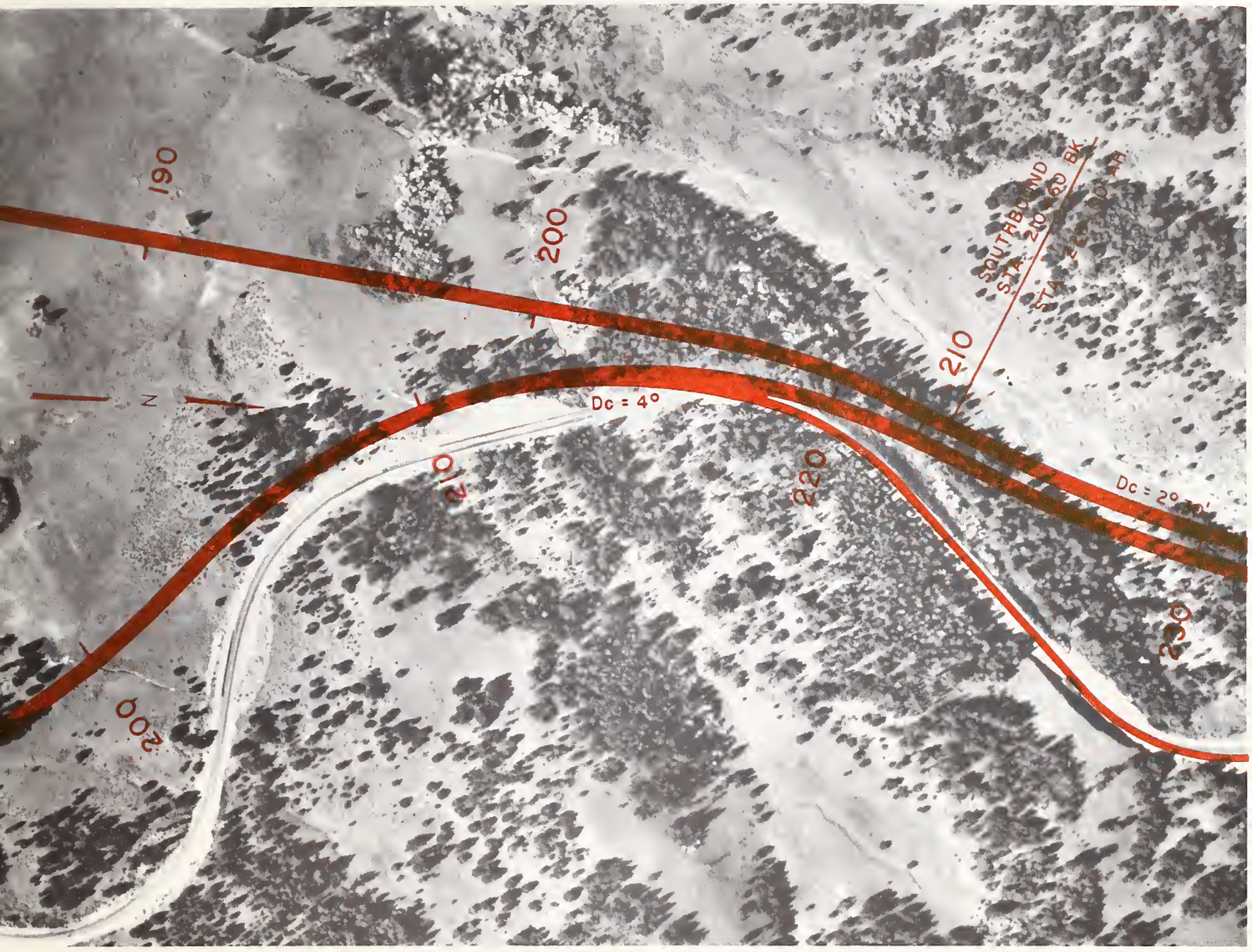


FIGURE 13



ALTERNATE 4

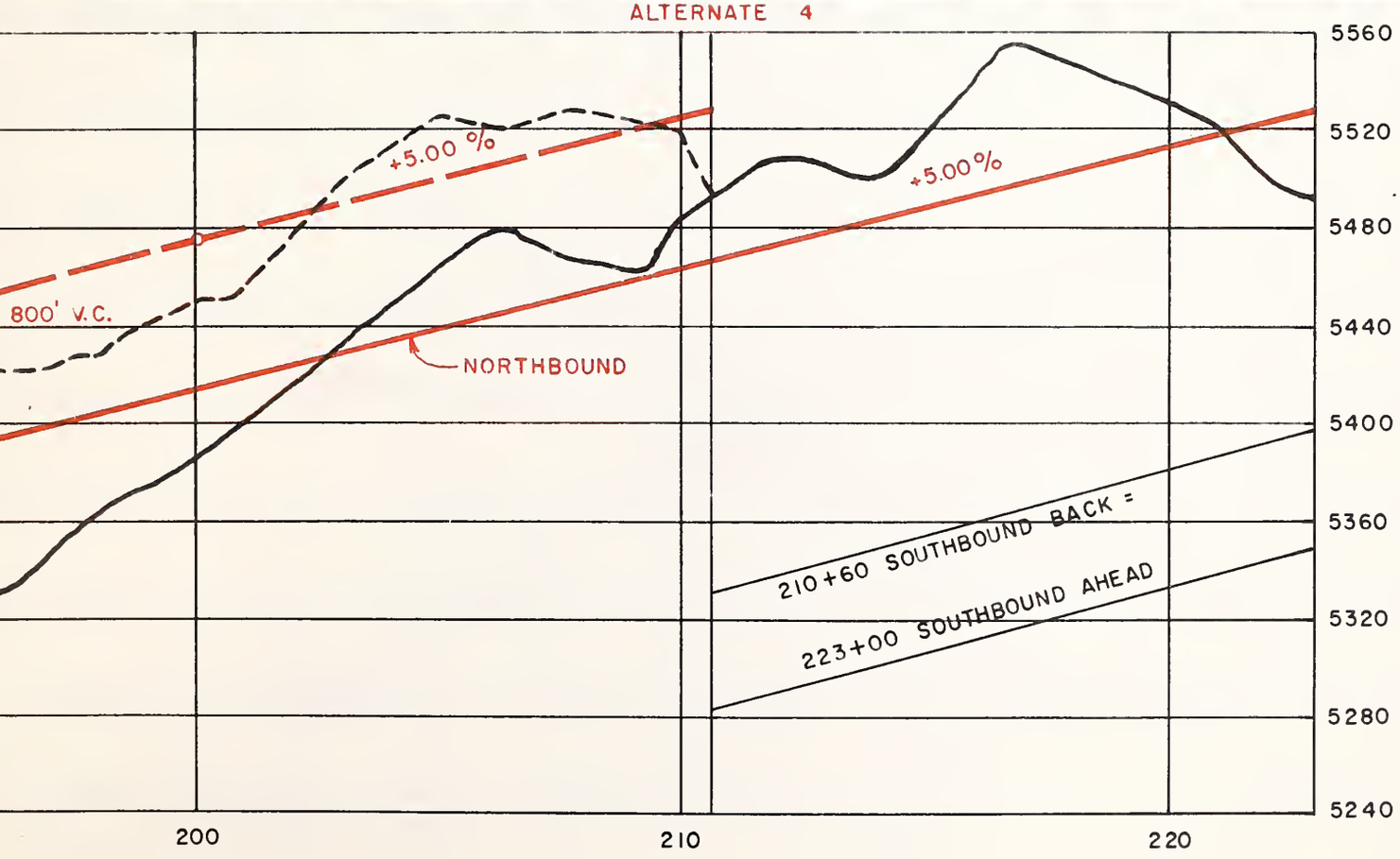
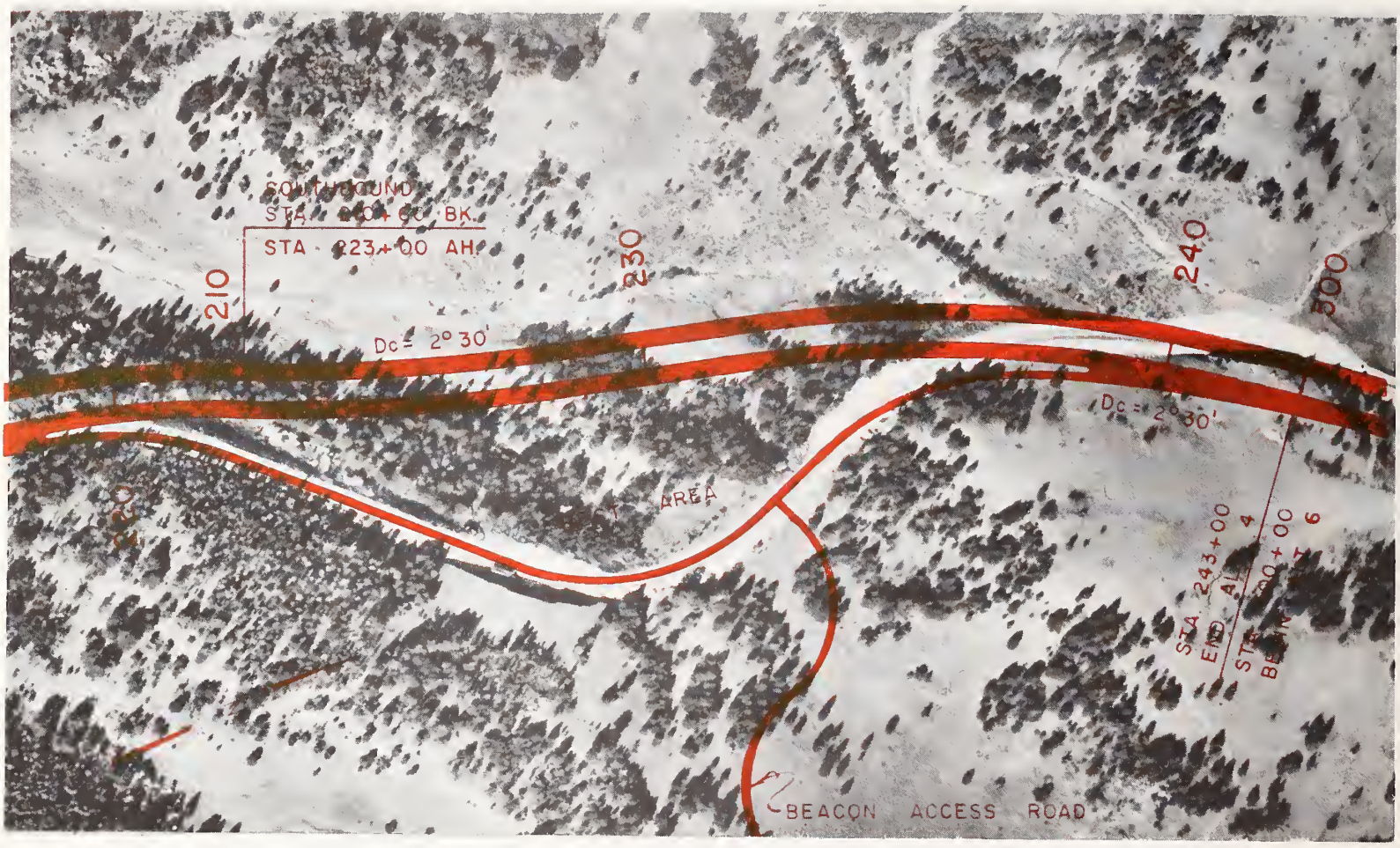
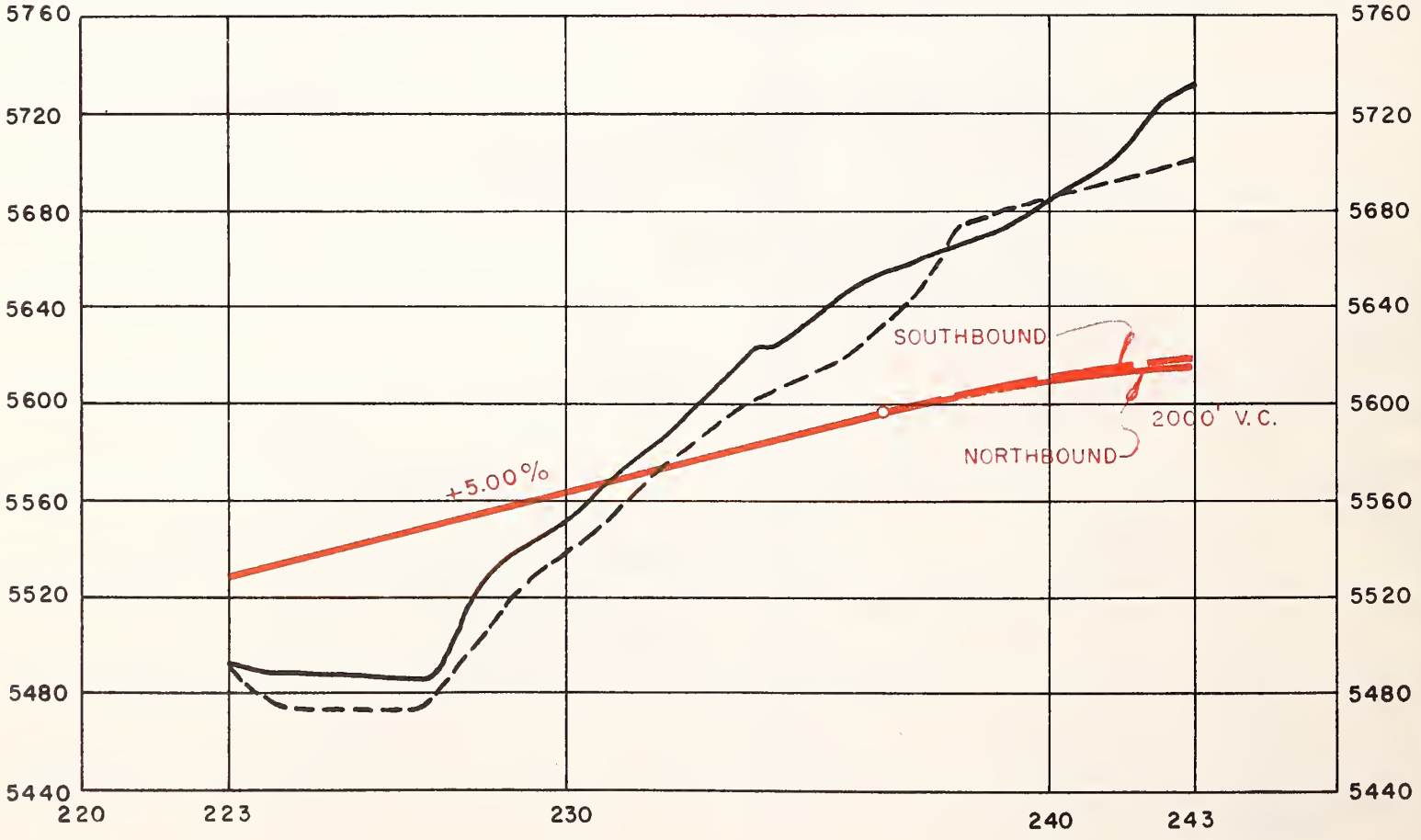
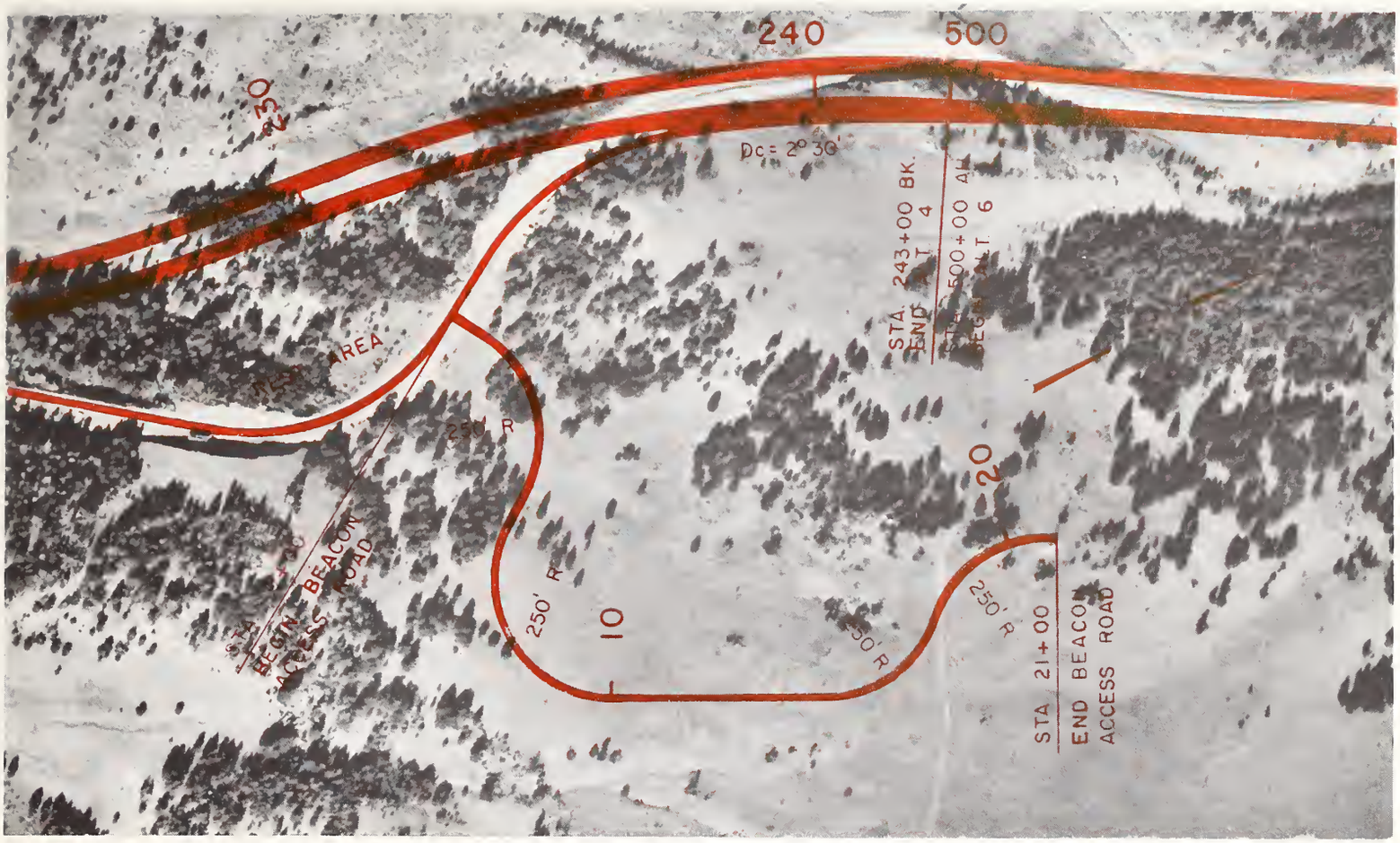


FIGURE 14



ALTERNATE 4





BEACON ACCESS ROAD

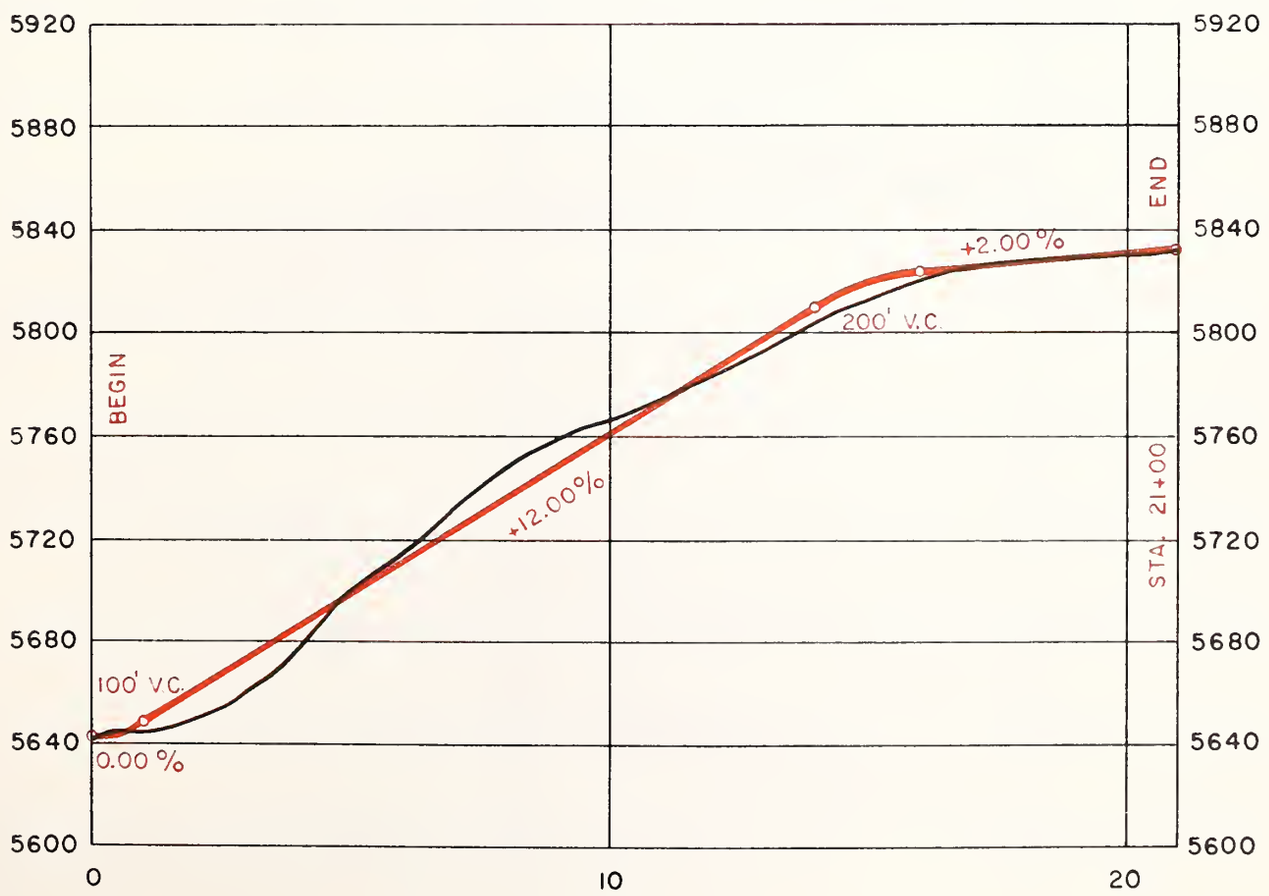
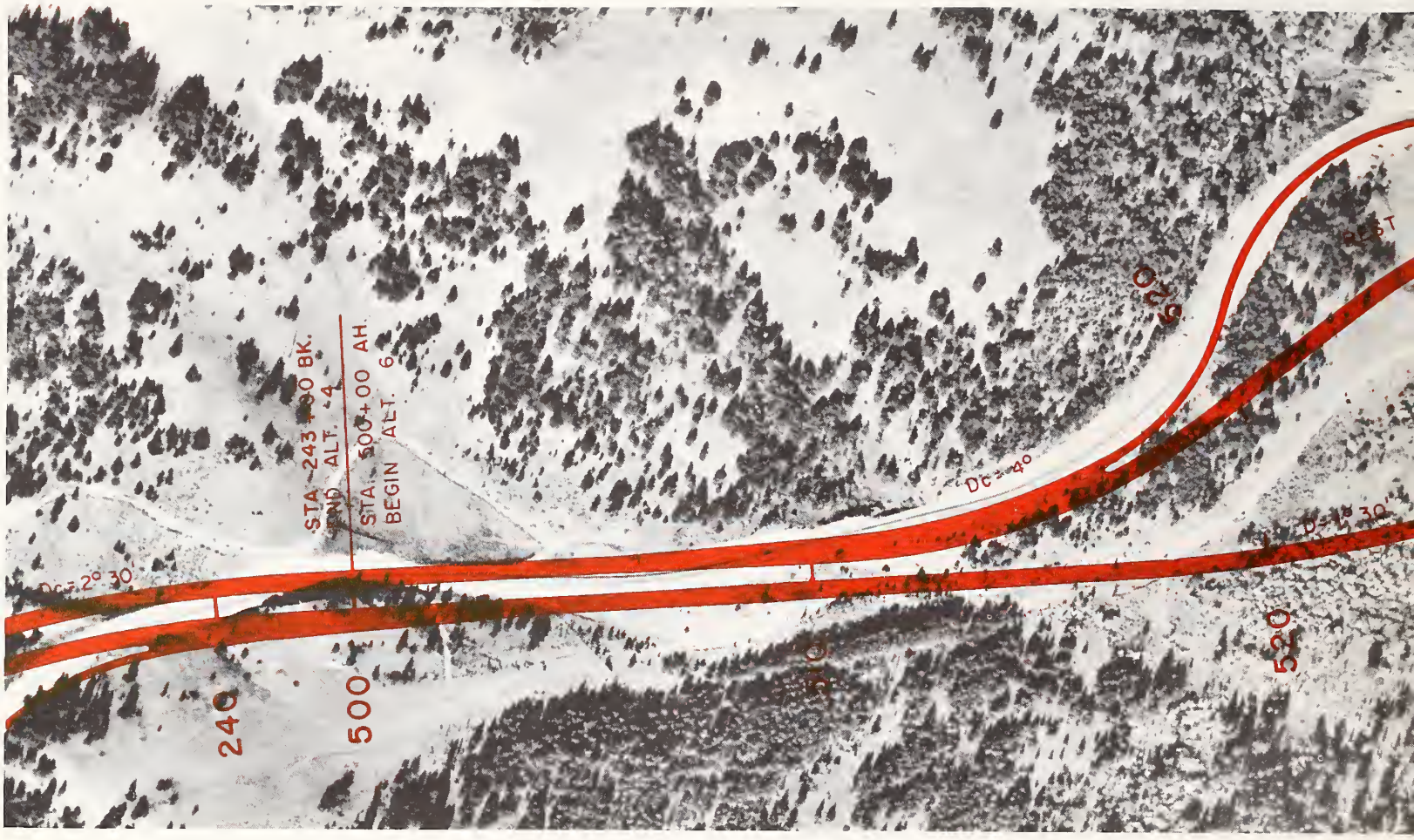
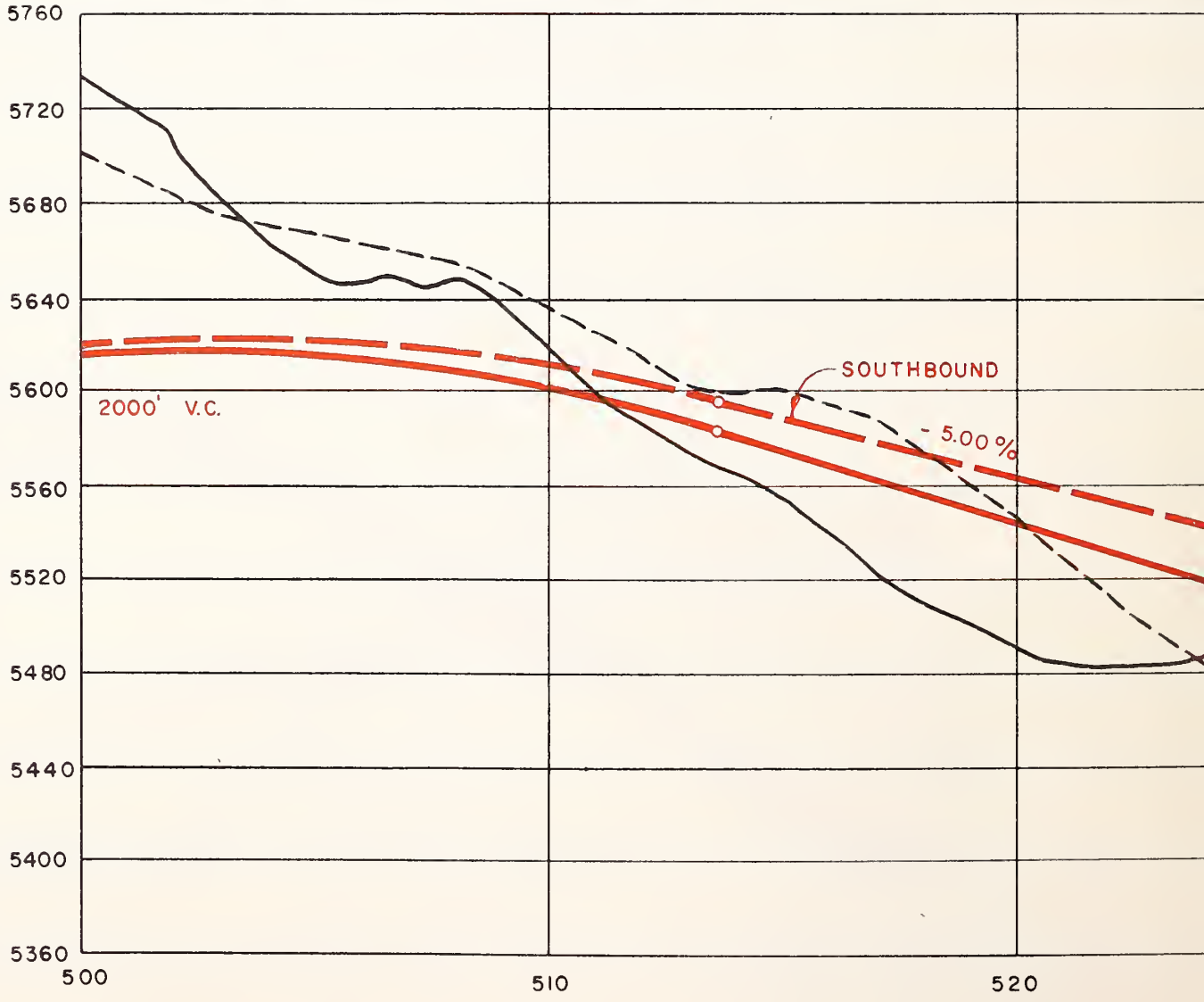
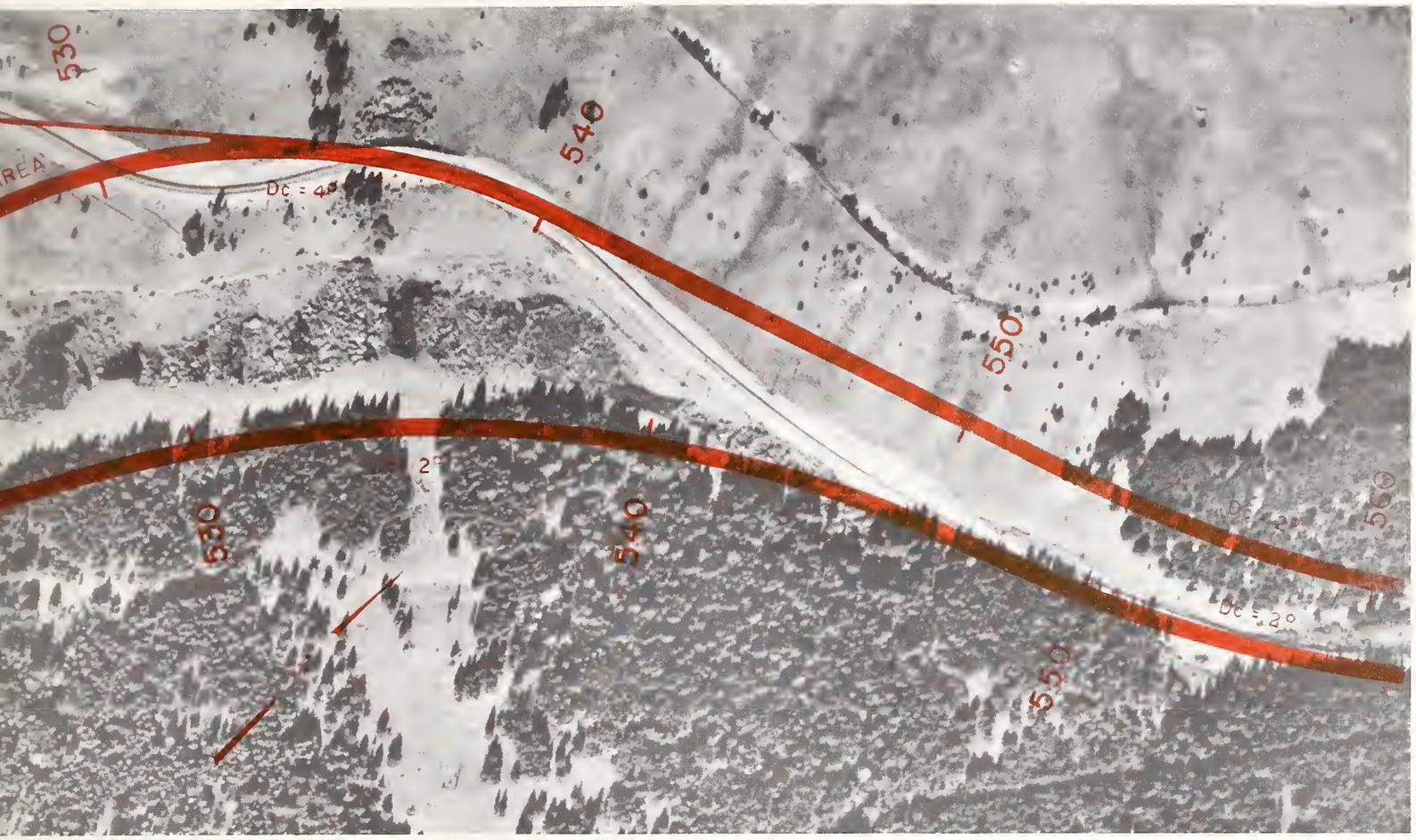


FIGURE 16



ALTERNATE 6




530
540
550
Dc = 4°
2°
Dc = 2°

ALTERNATE 6

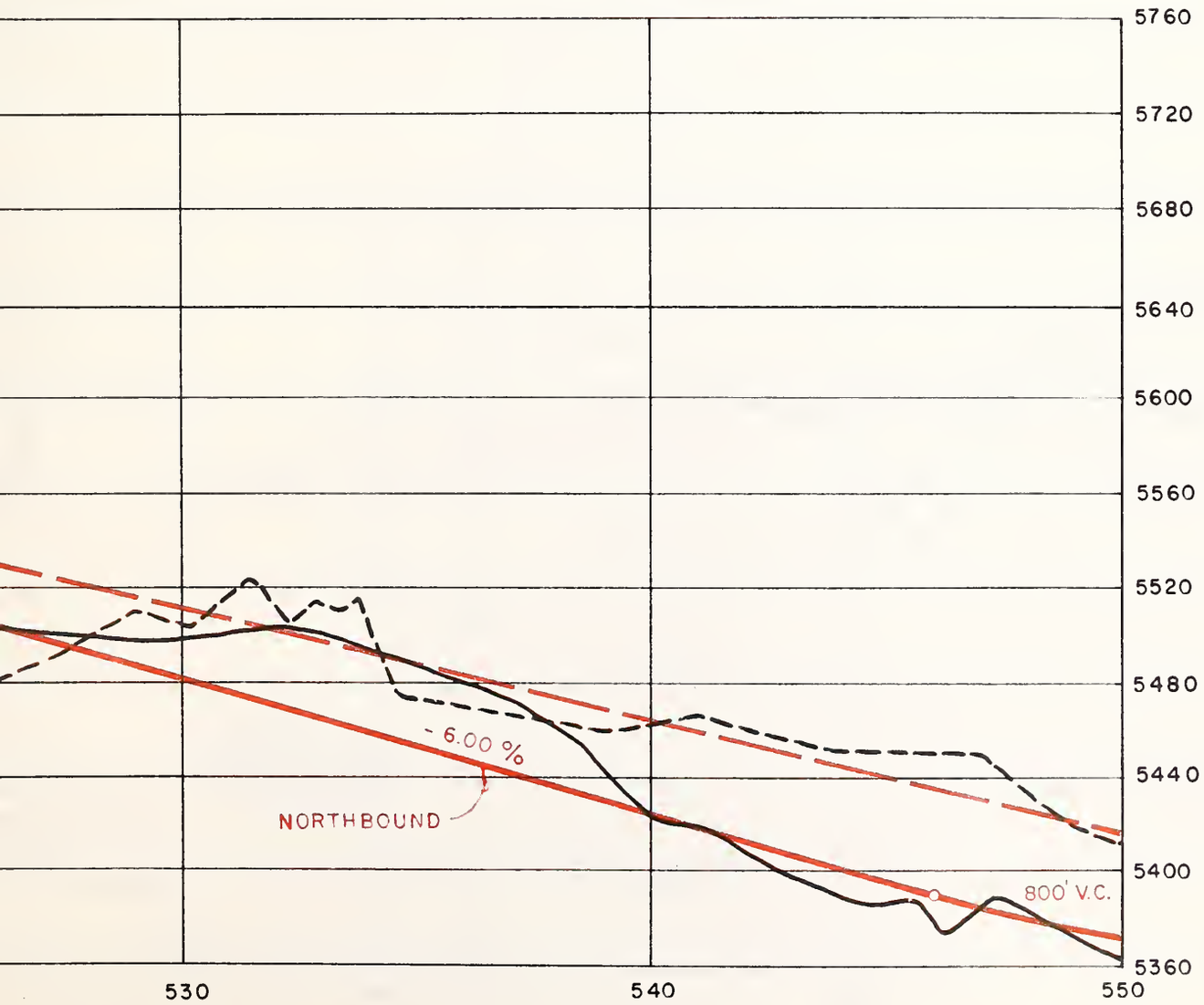
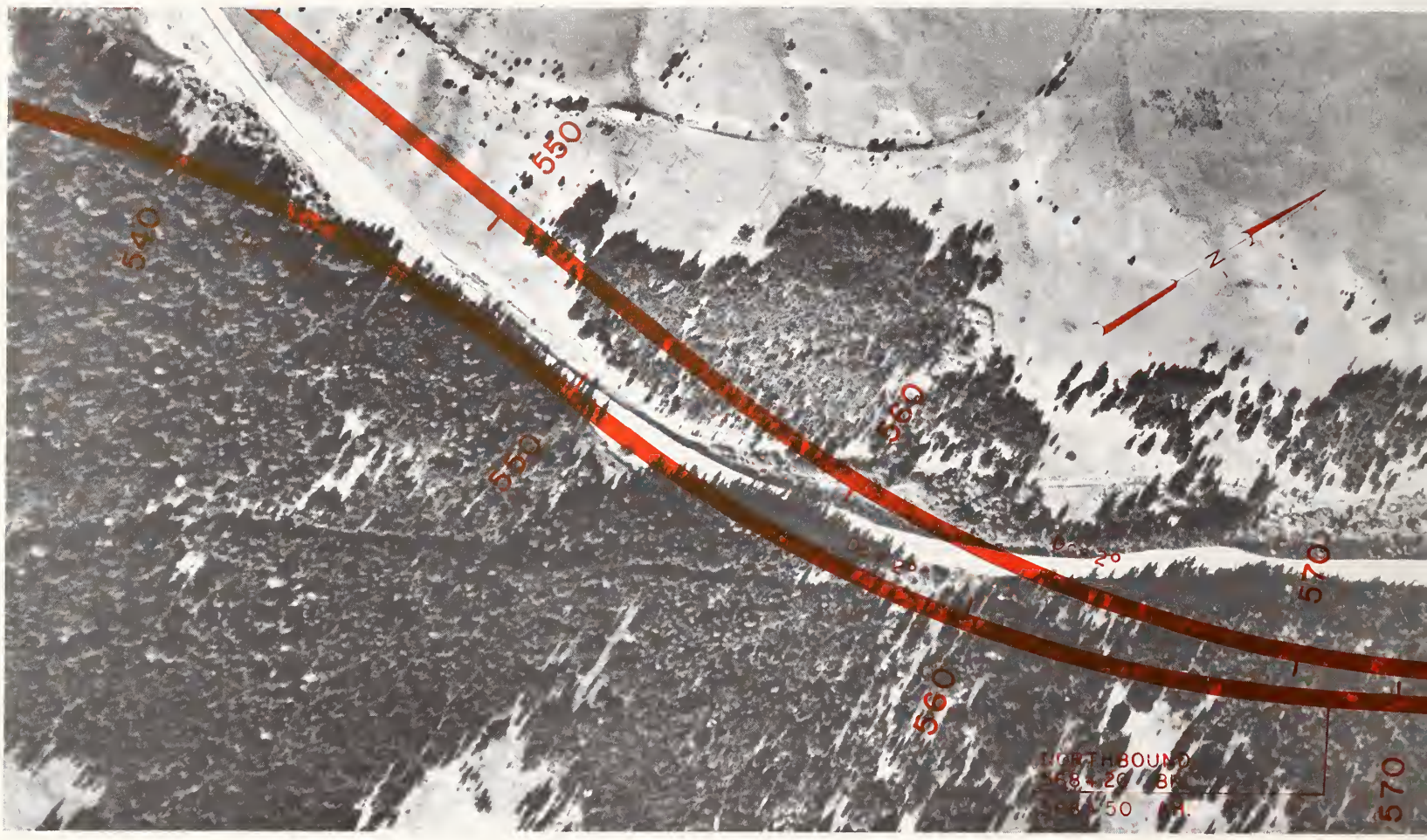

5760
5720
5680
5640
5600
5560
5520
5480
5440
5400
5360
530
540
550
-6.00 %
NORTHBOUND
800' V.C.

FIGURE 18



ALTERNATE 6

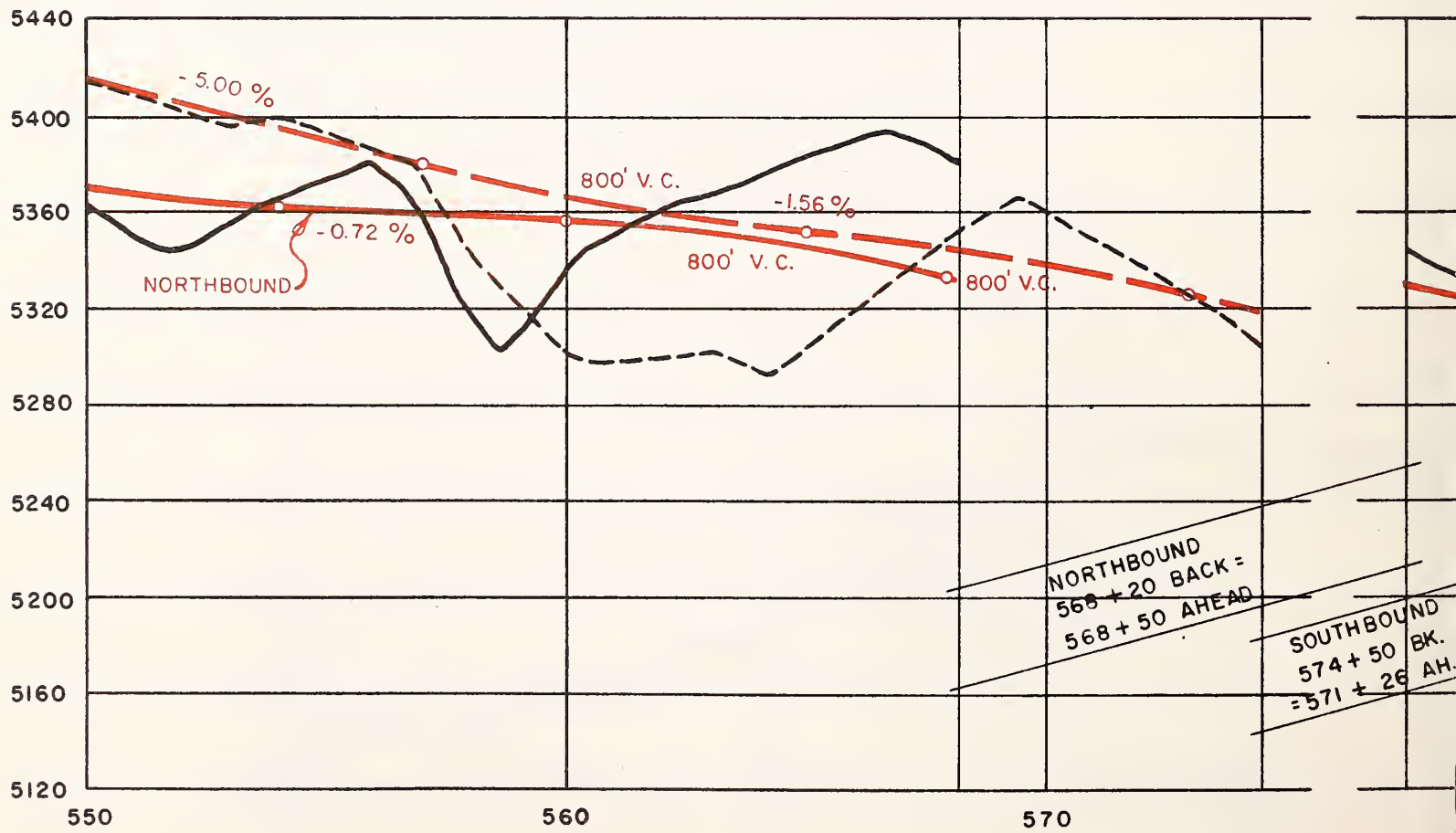
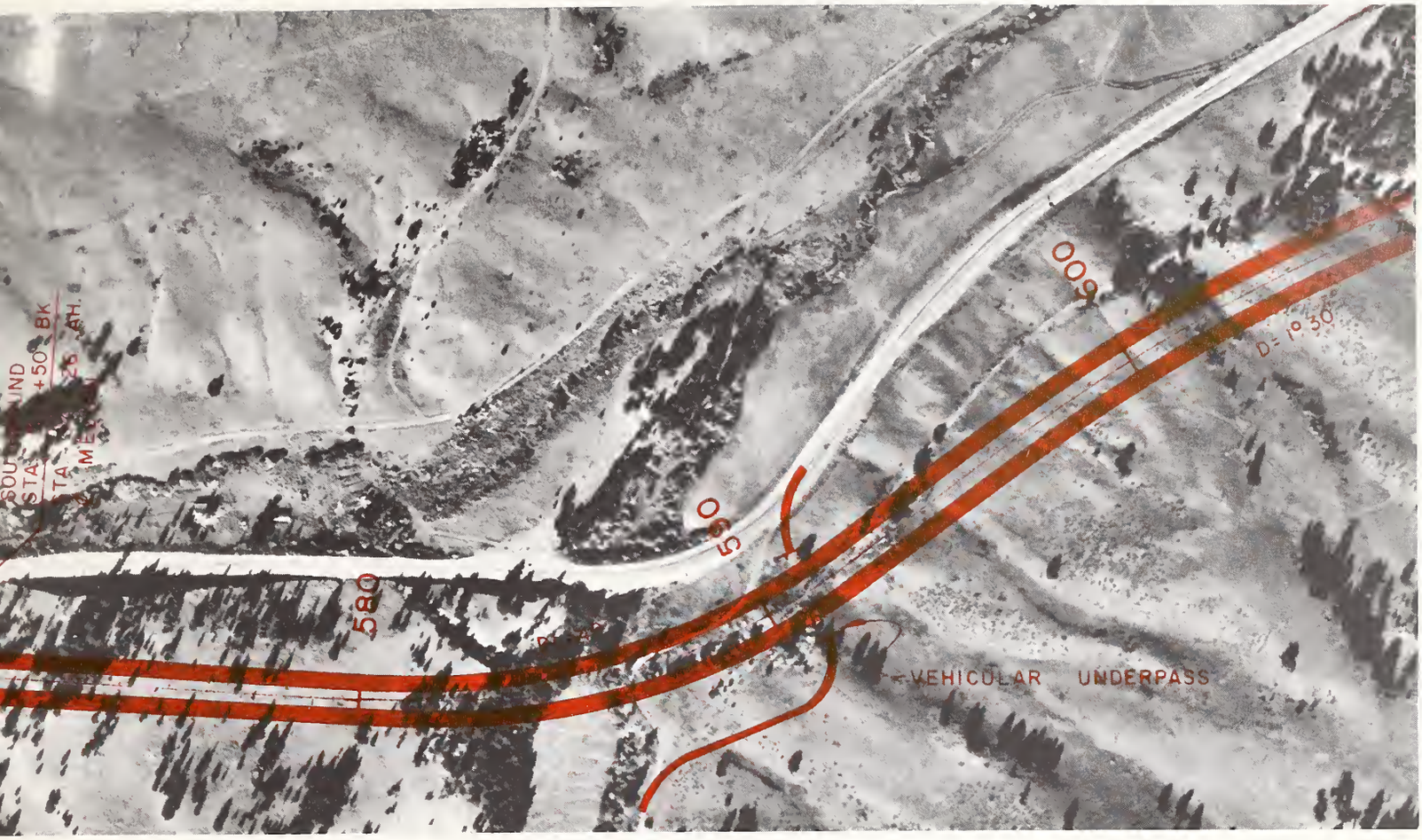


FIGURE 19



ALTERNATE 6

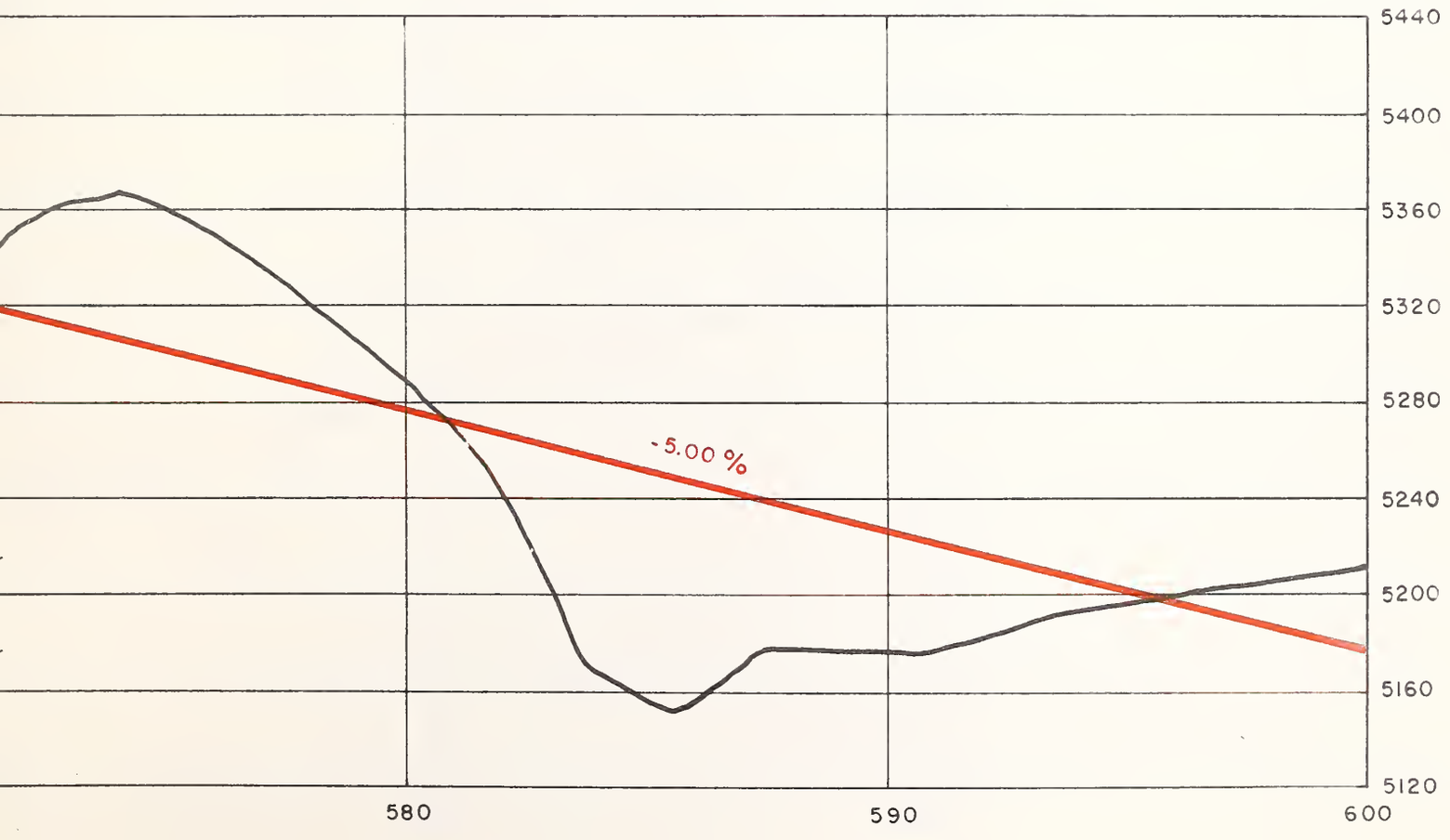
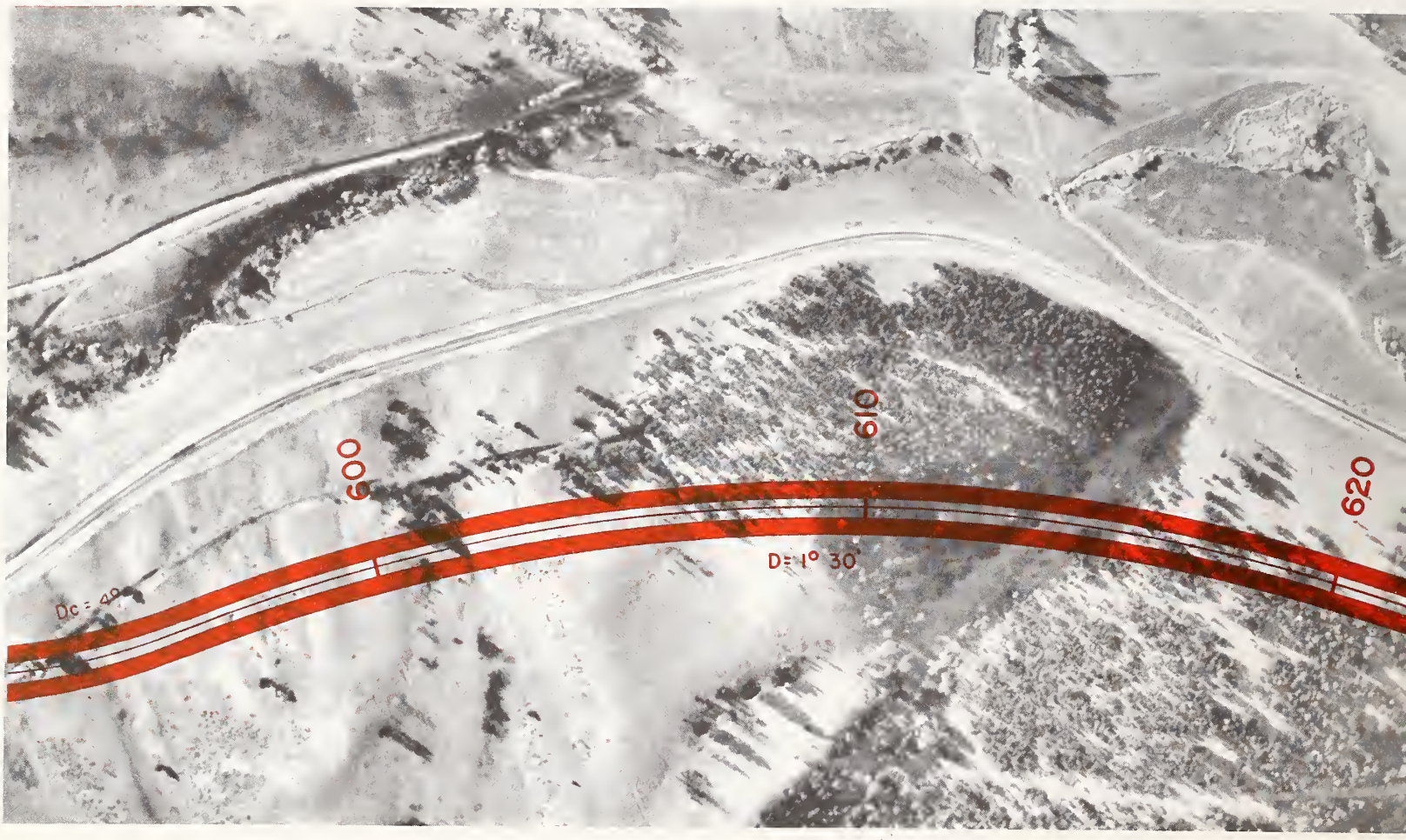


FIGURE 20



ALTERNATE 6

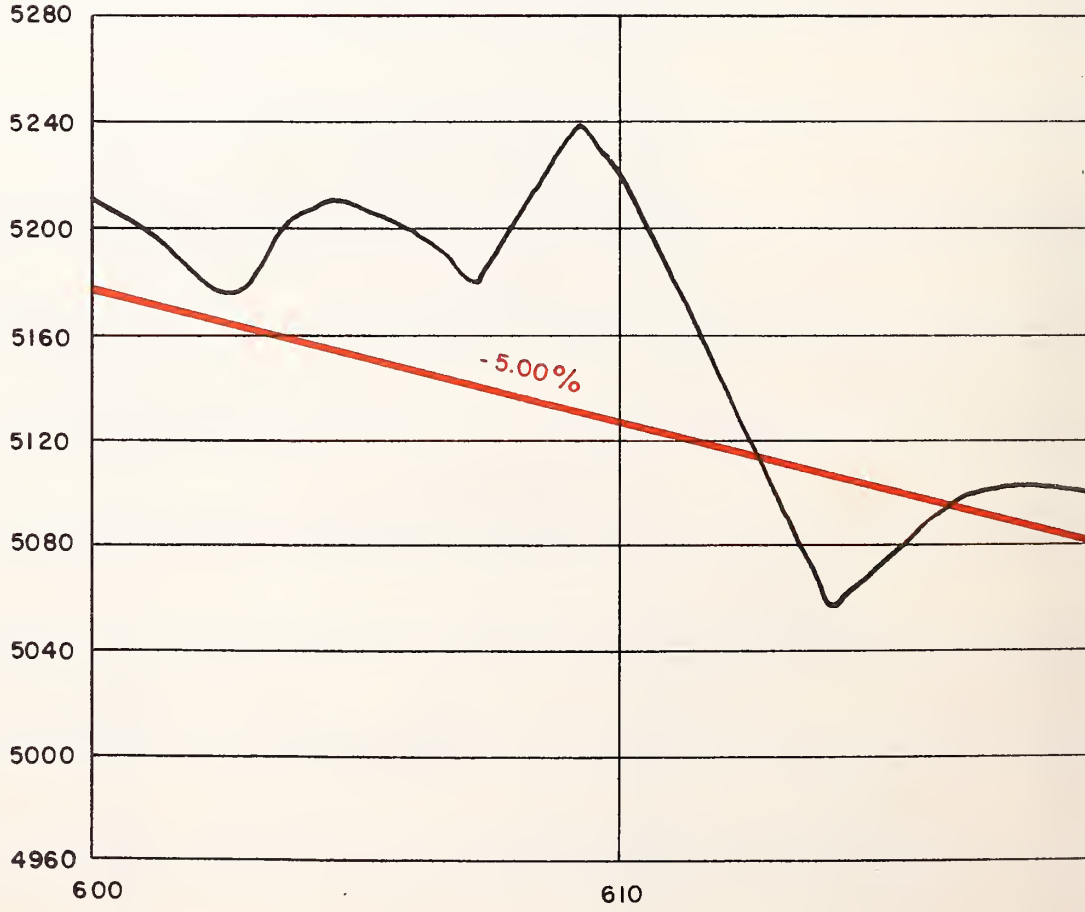
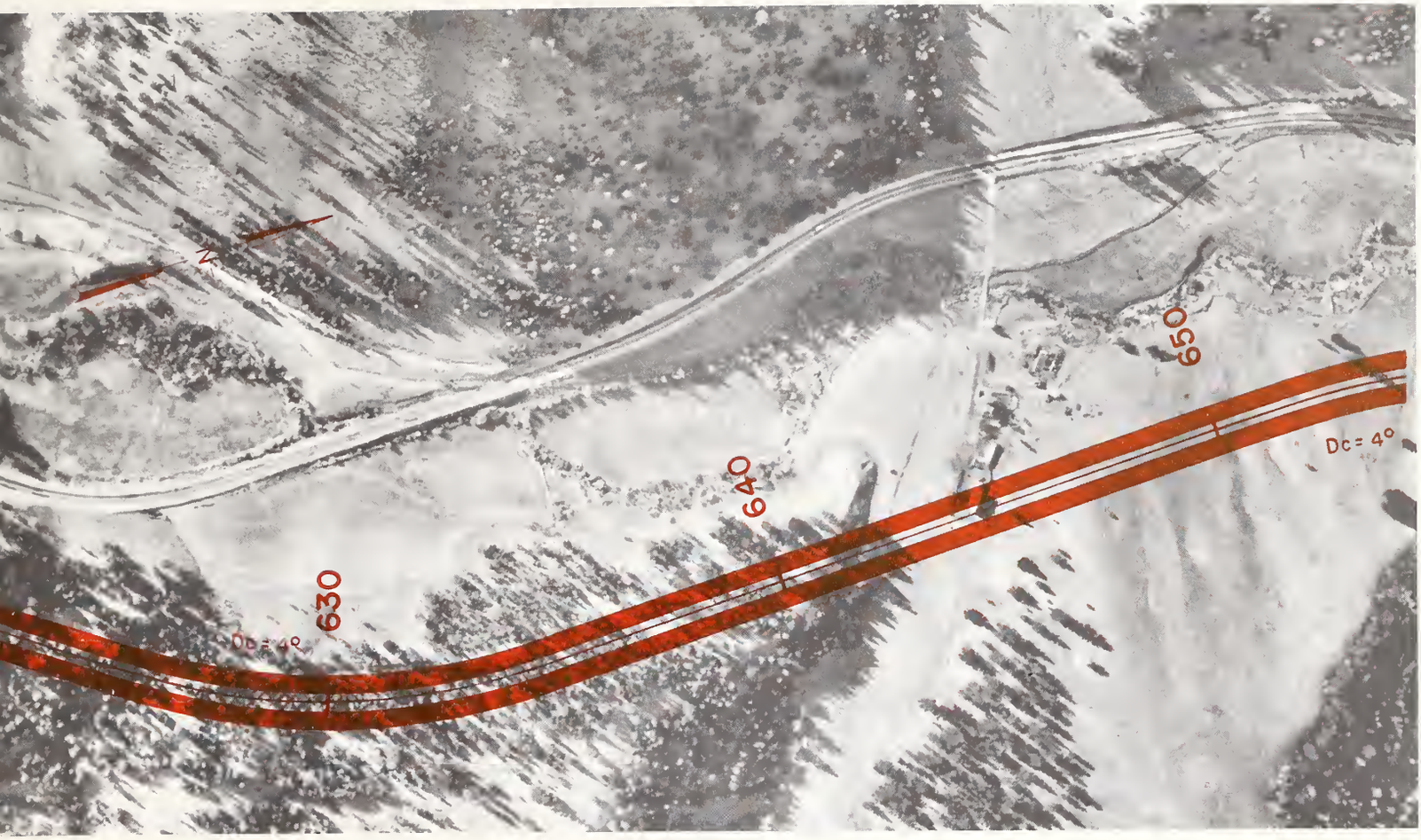


FIGURE 21



ALTERNATE 6

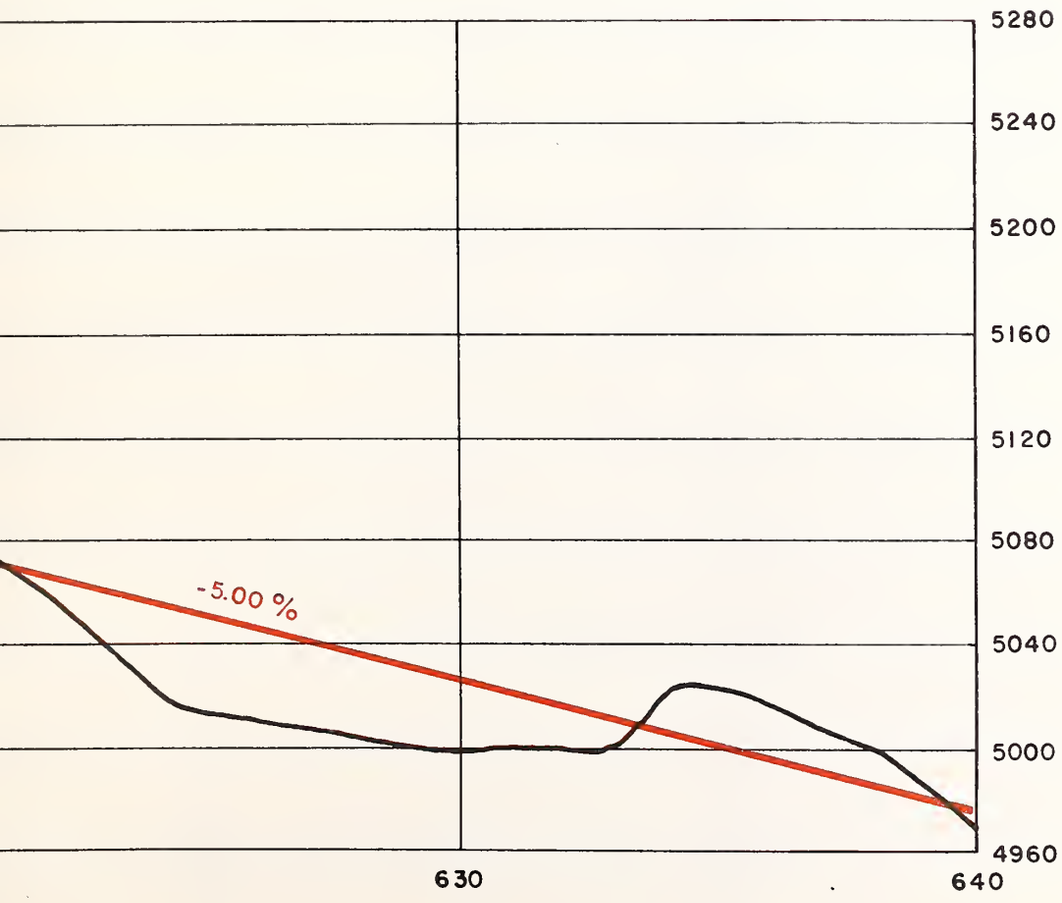
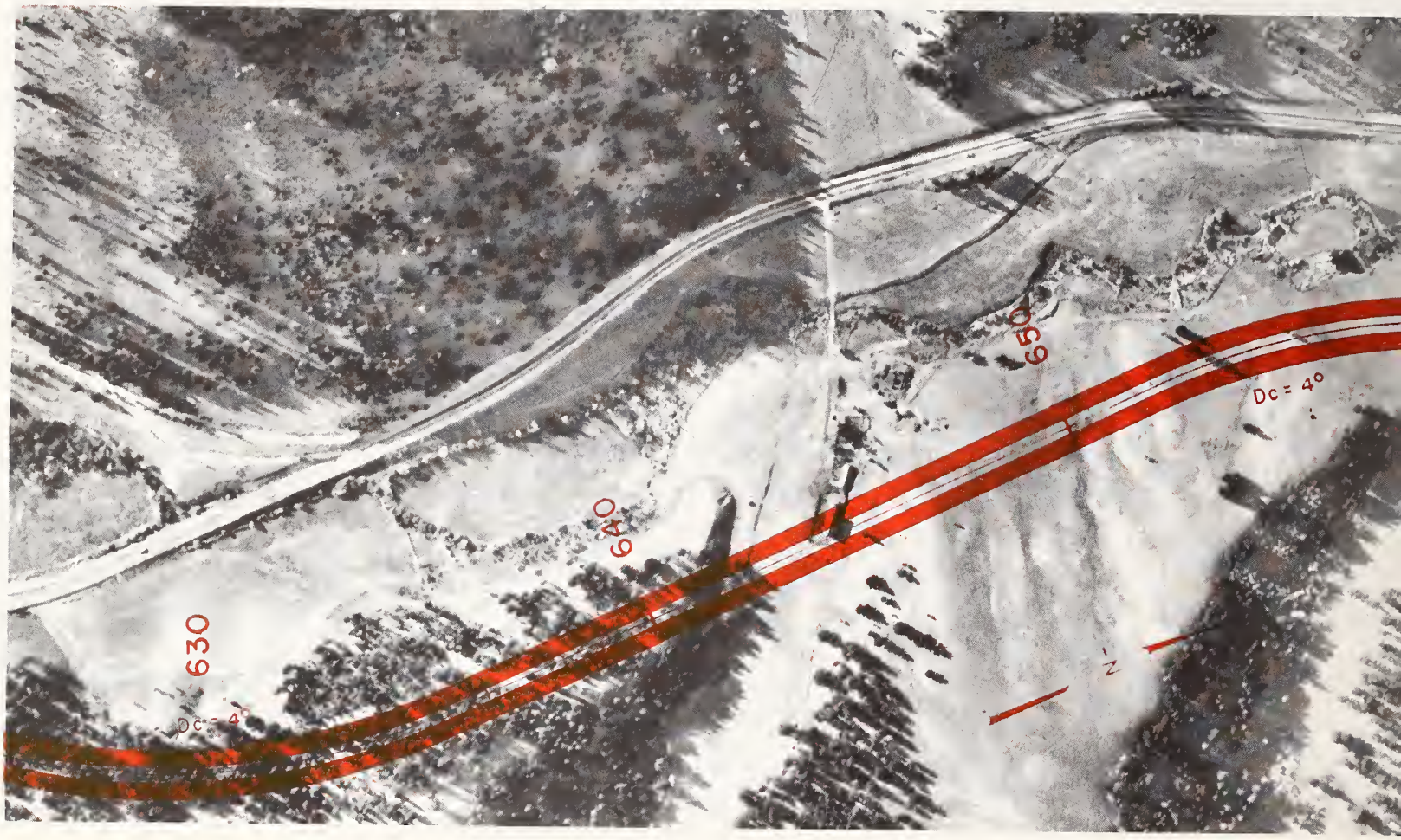


FIGURE 22



ALTERNATE 6

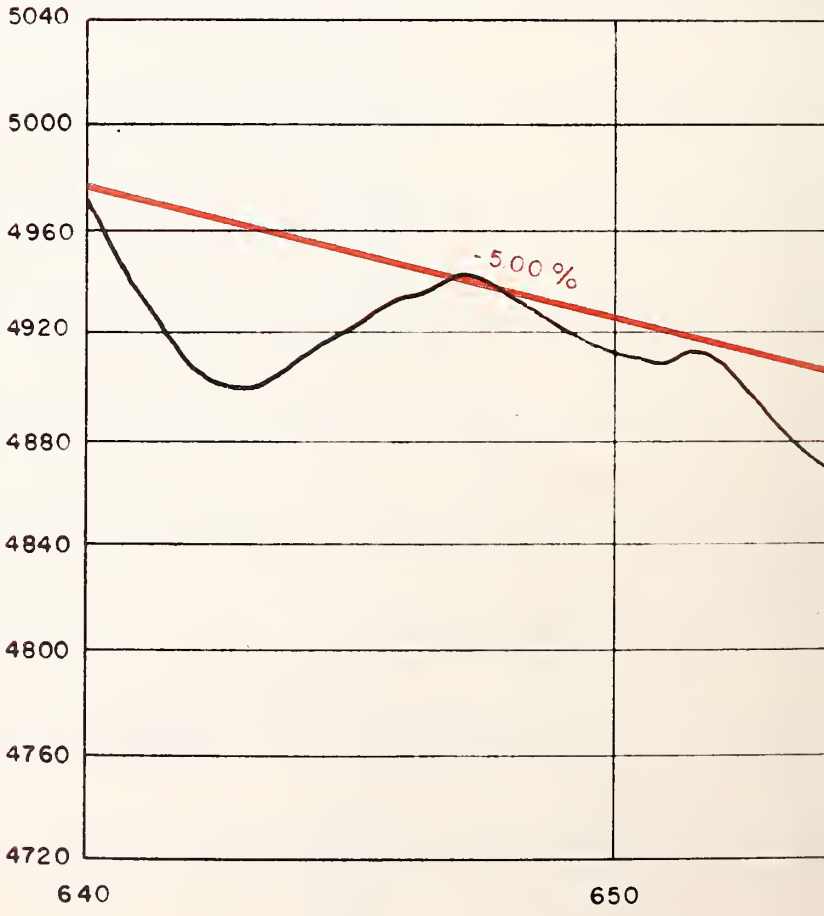
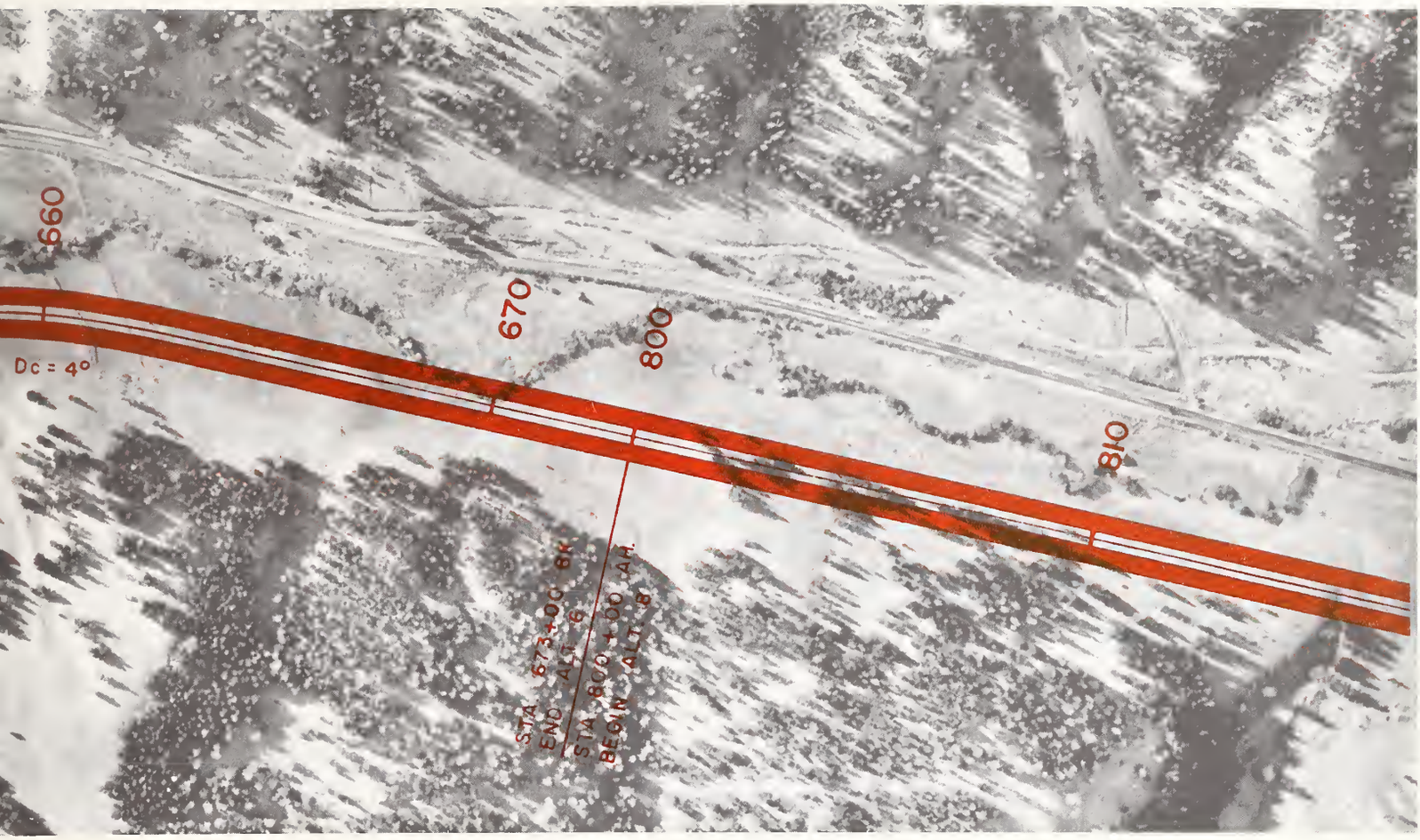


FIGURE 23



ALTERNATE 6

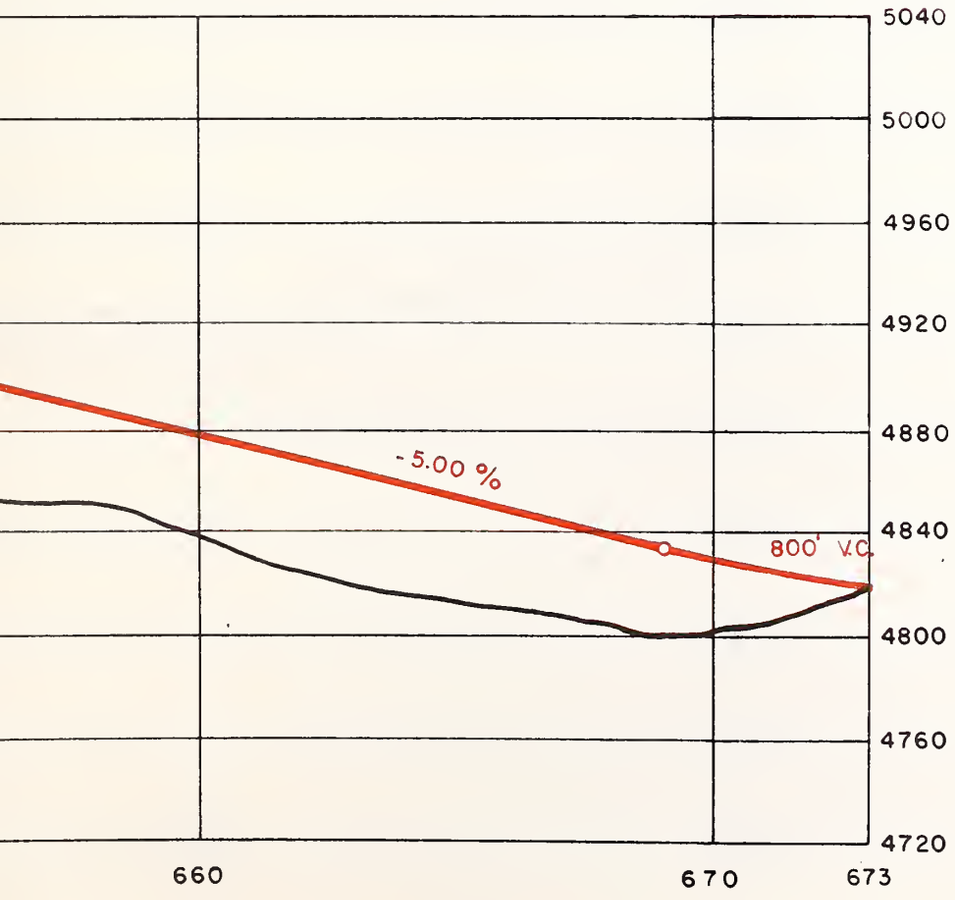
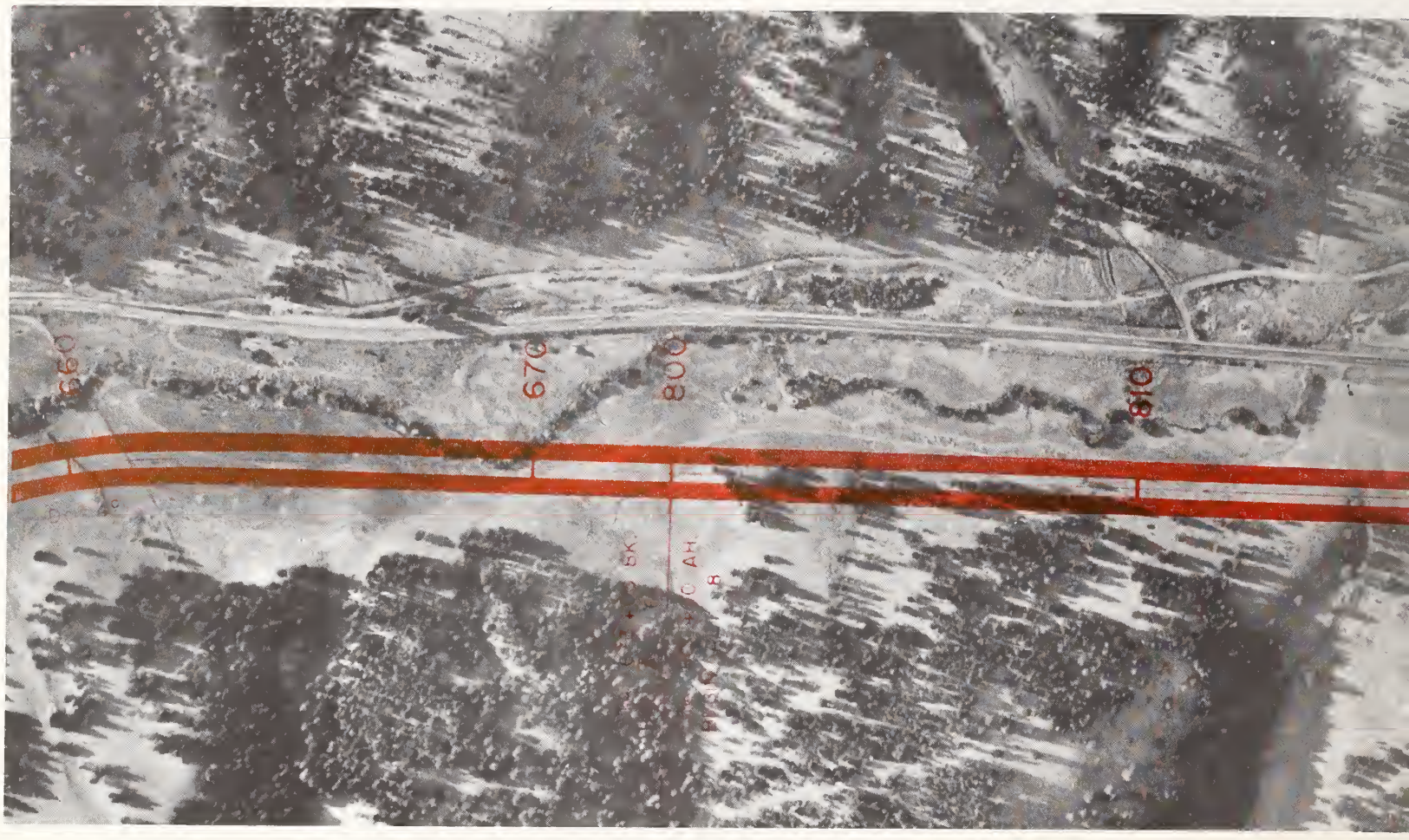
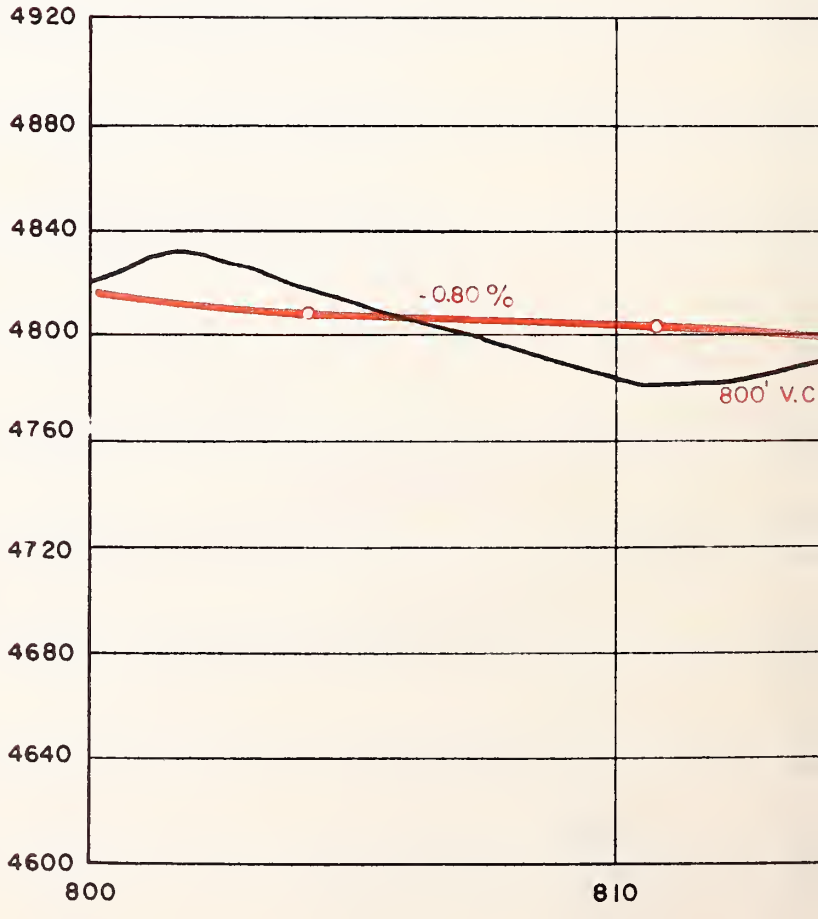


FIGURE 24



ALTERNATE 8



820
830
840
D= 0° 30'

ALTERNATE 8

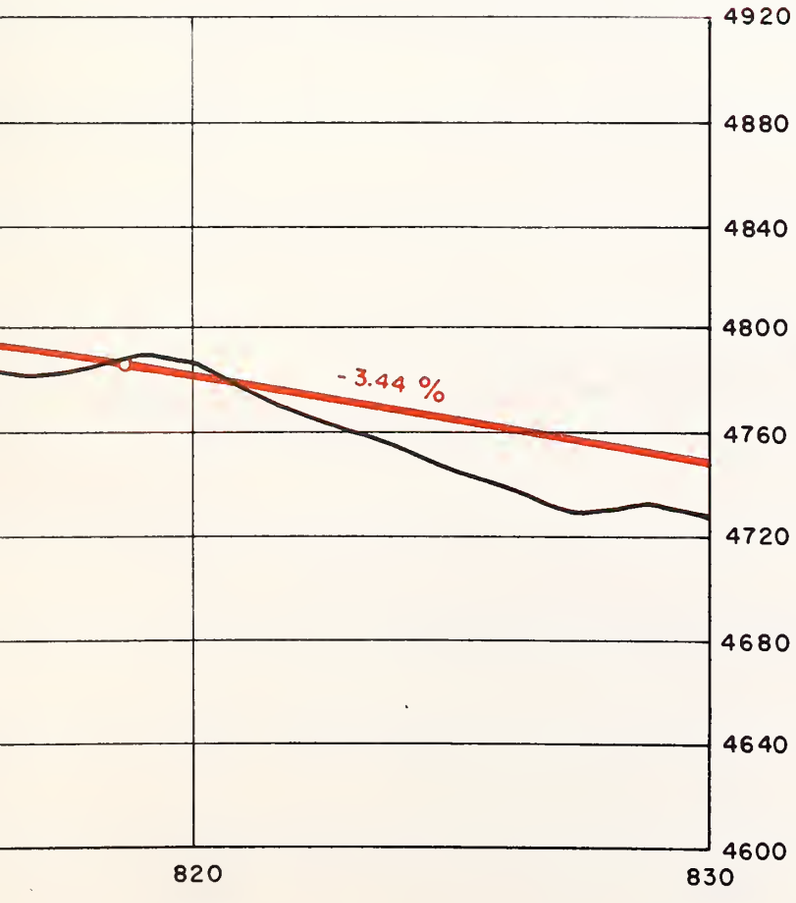
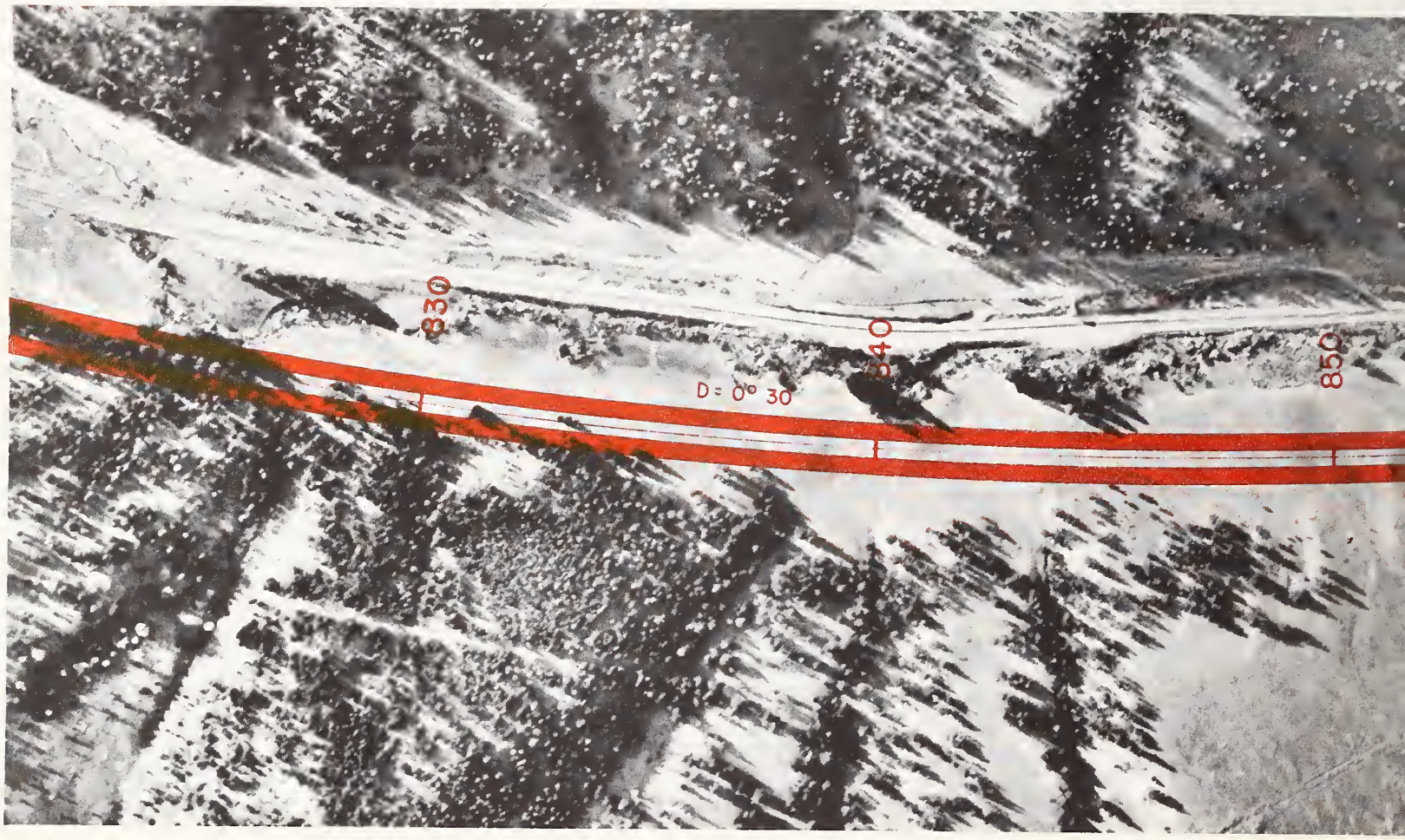

4920
4880
4840
4800
4760
4720
4680
4640
4600
-3.44 %
820
830

FIGURE 26



ALTERNATE 8

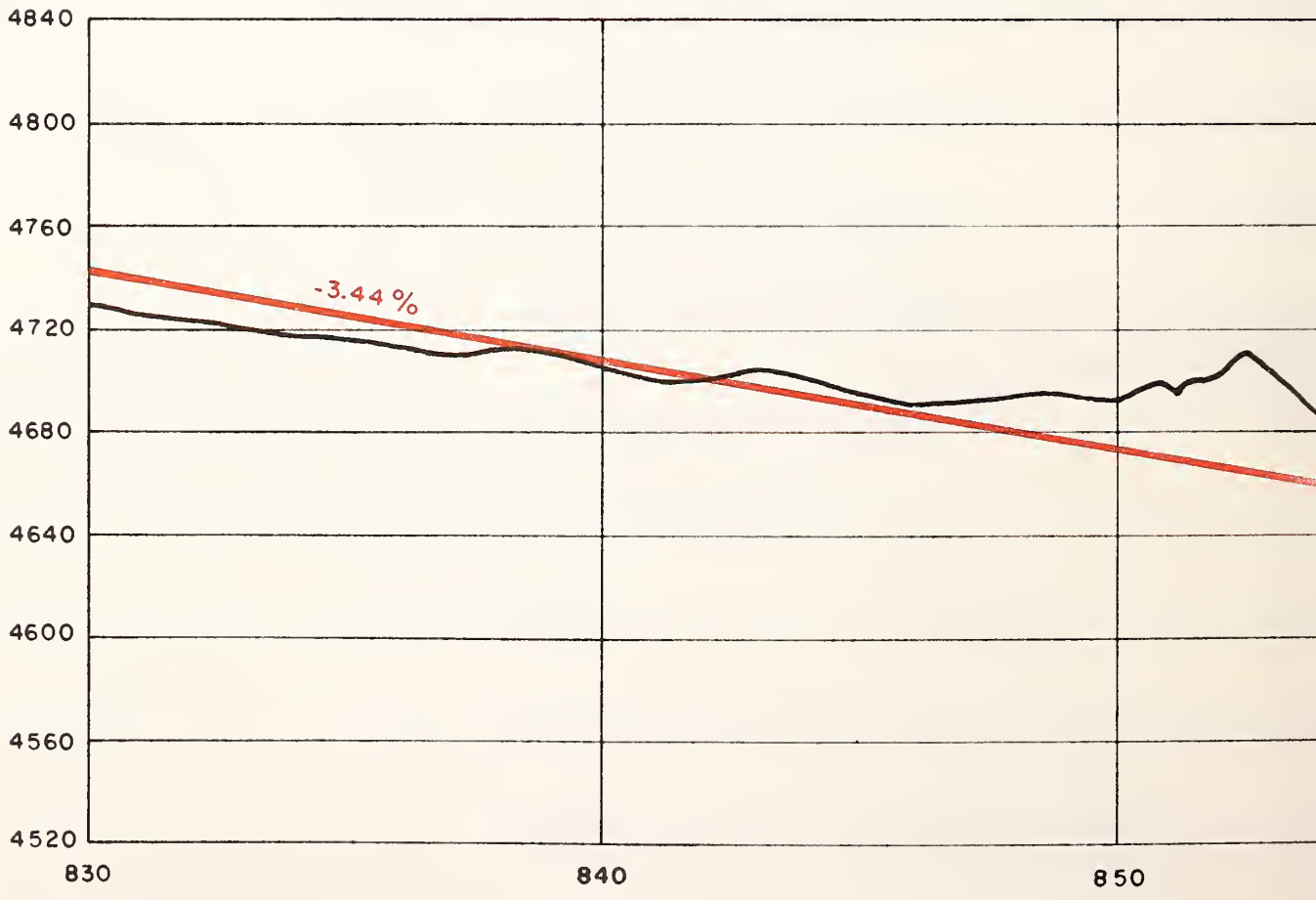
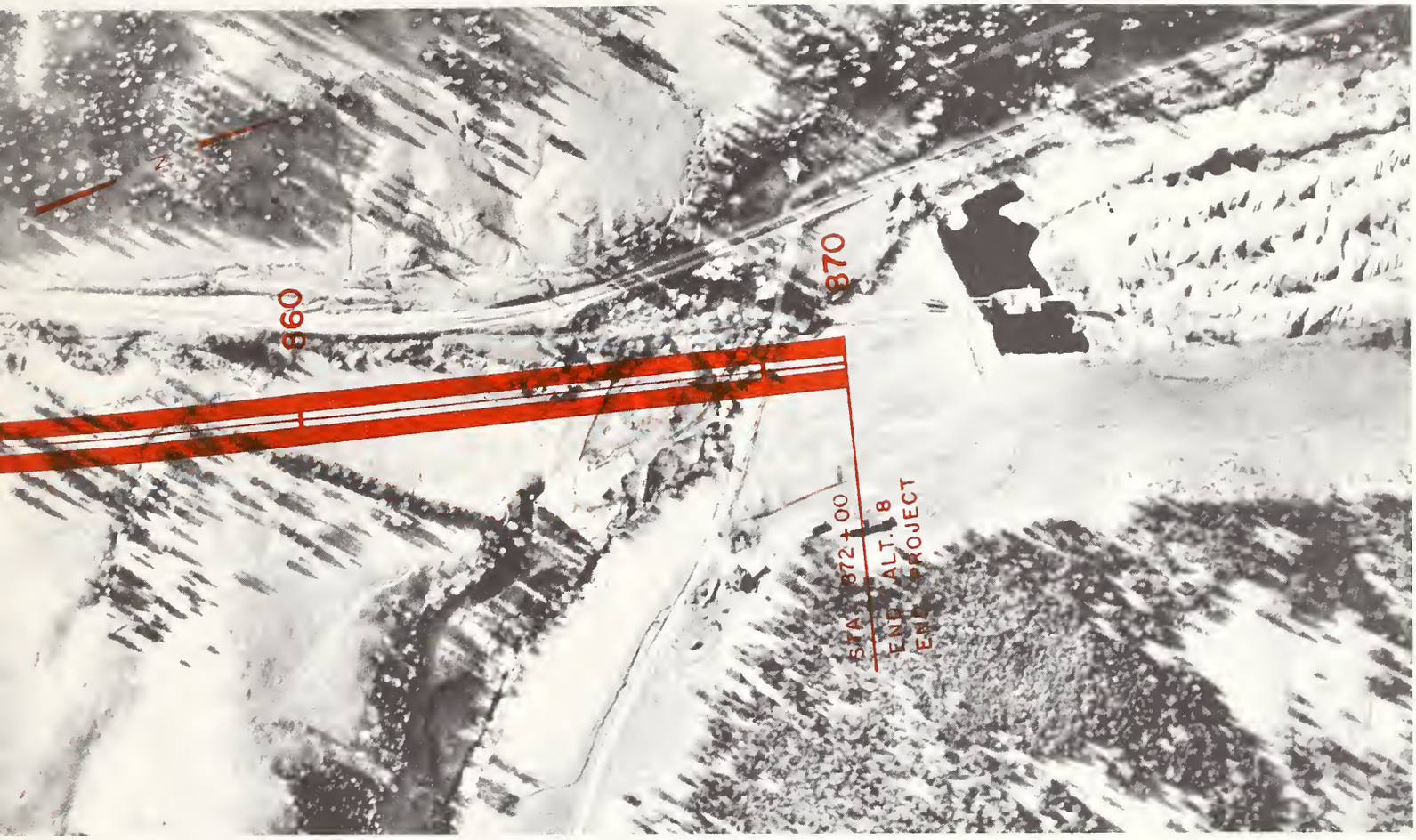


FIGURE 27



ALTERNATE 8

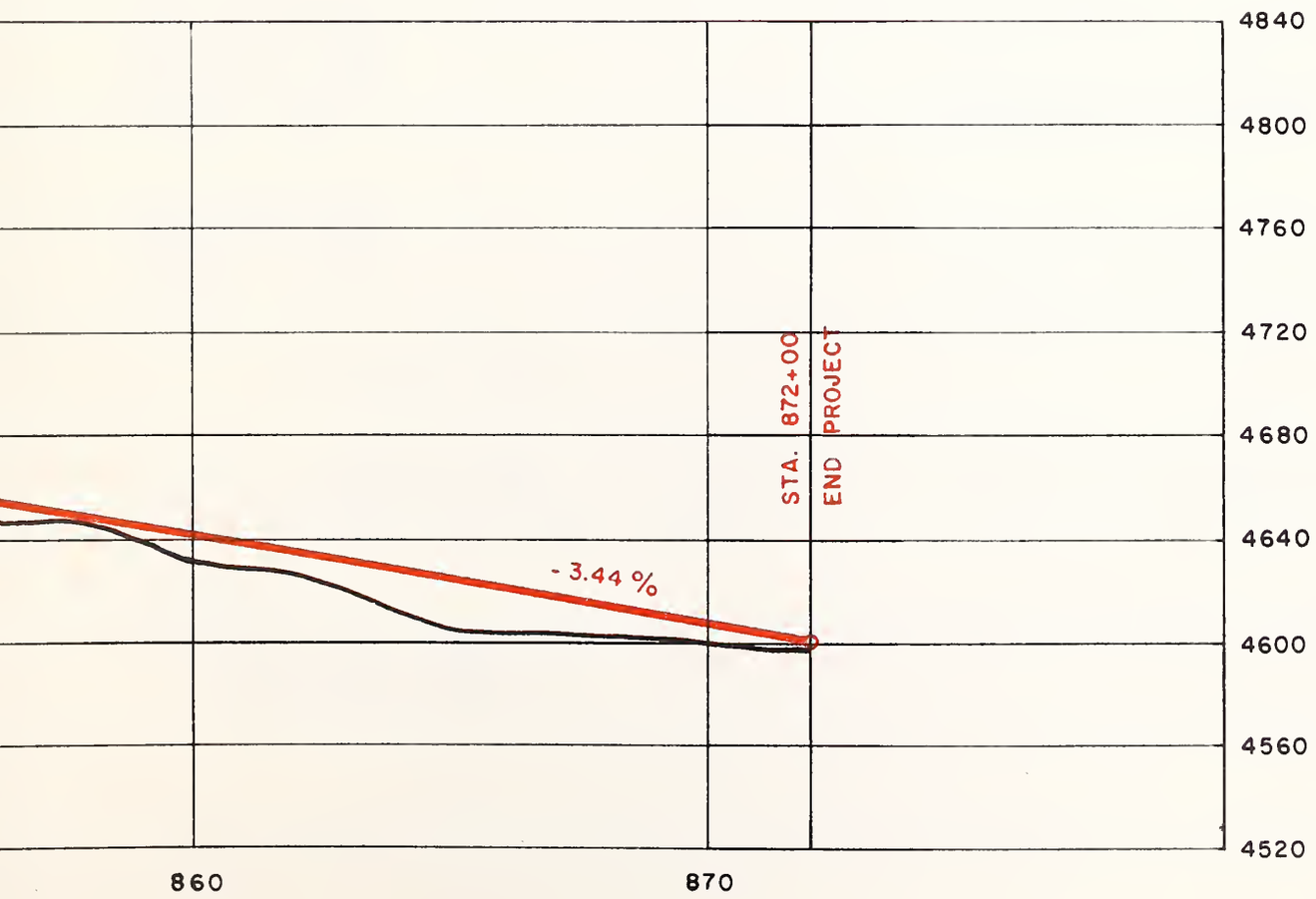


FIGURE 29

PLAN PROFILE LEGEND

PLAN DATA

SCALE: 1"= 400'

ALIGNMENT 1, 3, 5, 7

FRONTAGE ROADS,
ACCESS ROADS,
& REST AREAS

STRUCTURE

VEHICULAR UNDERPASS

D = DEGREE OF CURVATURE, SIMPLE CURVE
D_c = DEGREE OF CURVATURE, SPIRAL CURVE

CHANNEL CHANGE

PROFILE DATA

SCALE: HORIZONTAL 1"= 400' , VERTICAL 1"= 80'

NORTHBOUND
GROUND LINE

GRADE LINE

SOUTHBOUND
GROUND LINE

GRADE LINE

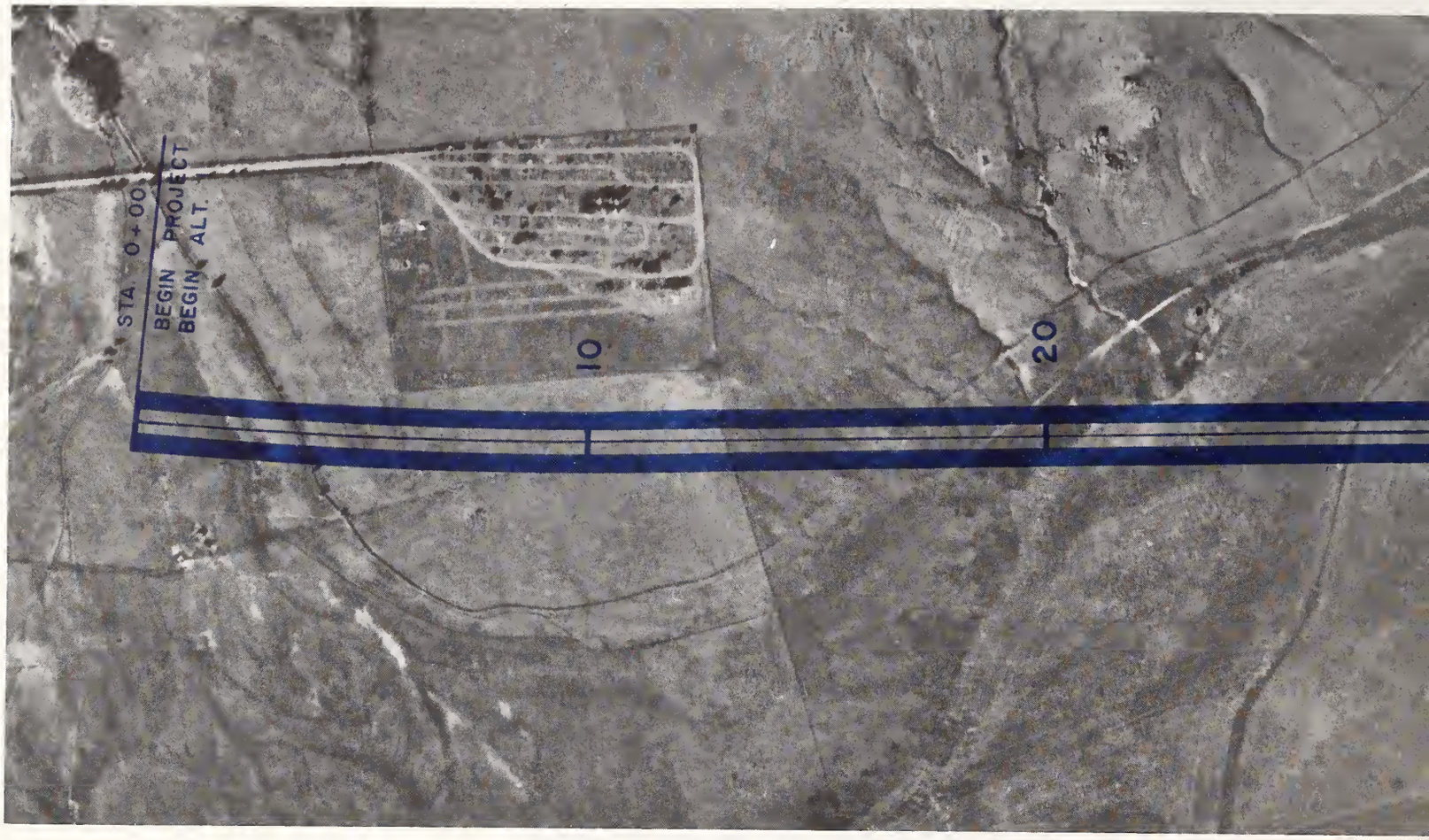
V. C. = VERTICAL CURVE

POINT OF CURVATURE TO POINT OF TANGENCY ON VERTICAL CURVE

NOTE

WHEN ONLY ONE GROUND & GRADE LINE IS SHOWN, PROFILE IS CENTER OF MEDIAN

FIGURE 30



ALTERNATE 1

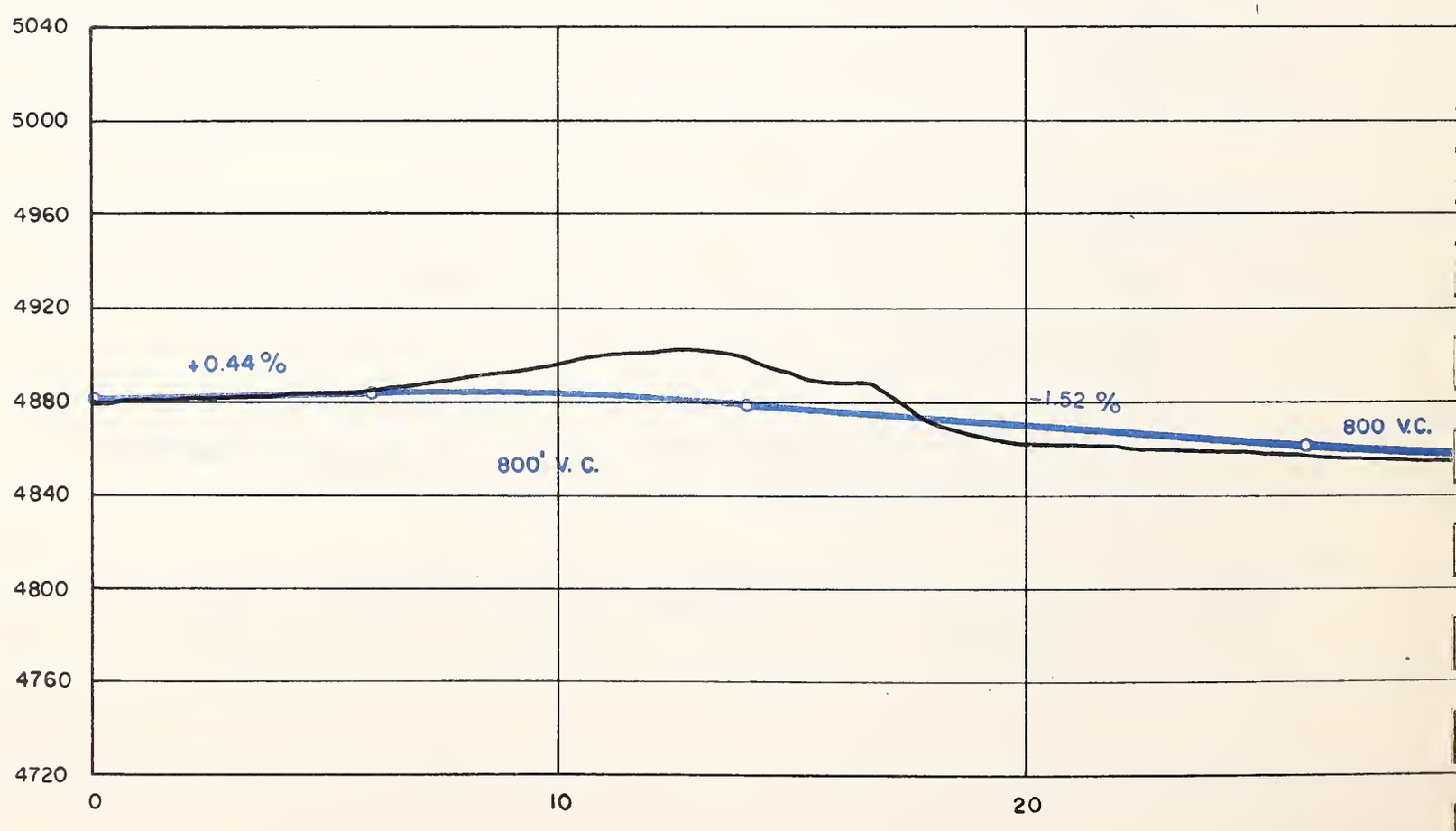
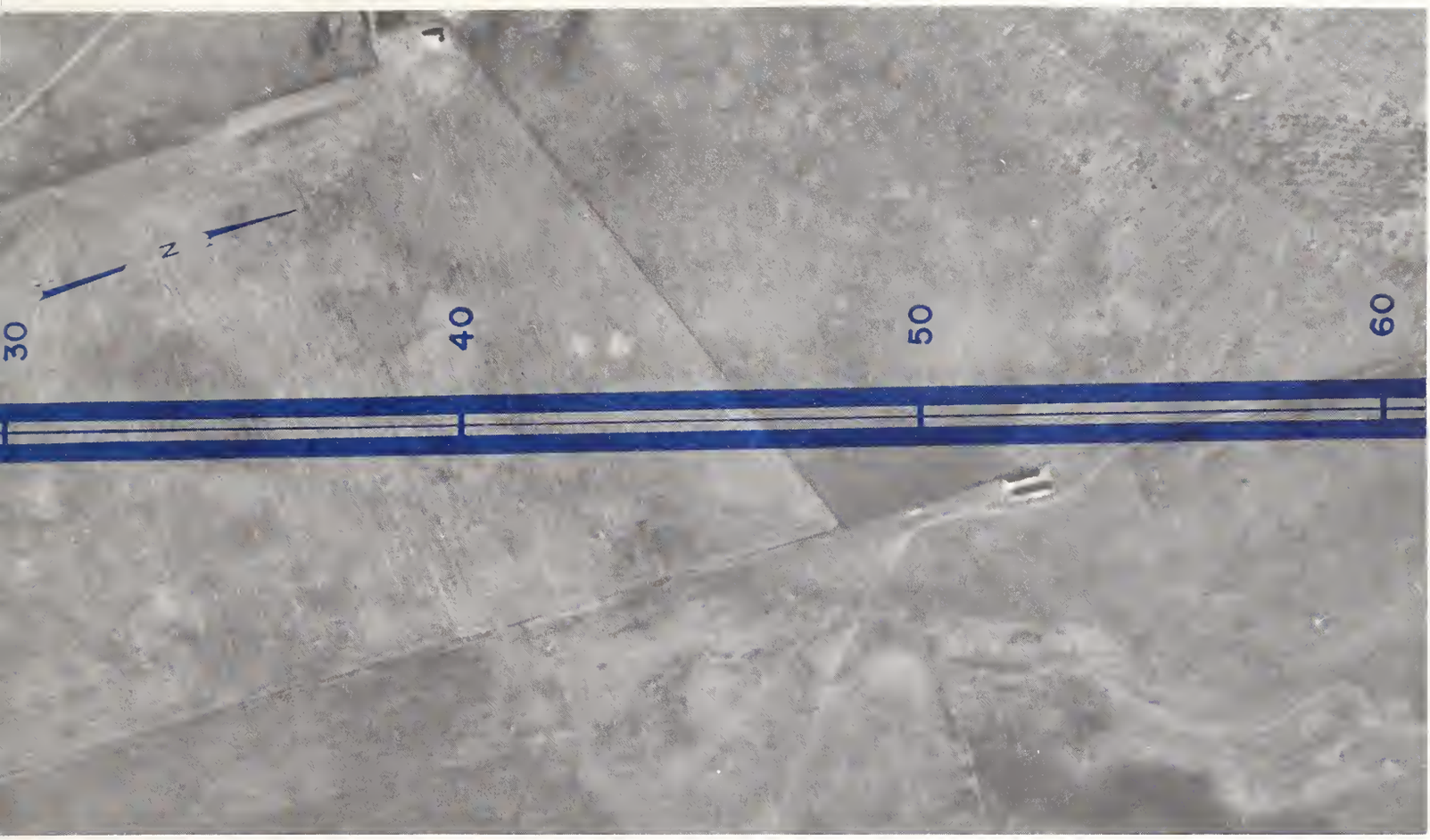


FIGURE 31



ALTERNATE 1

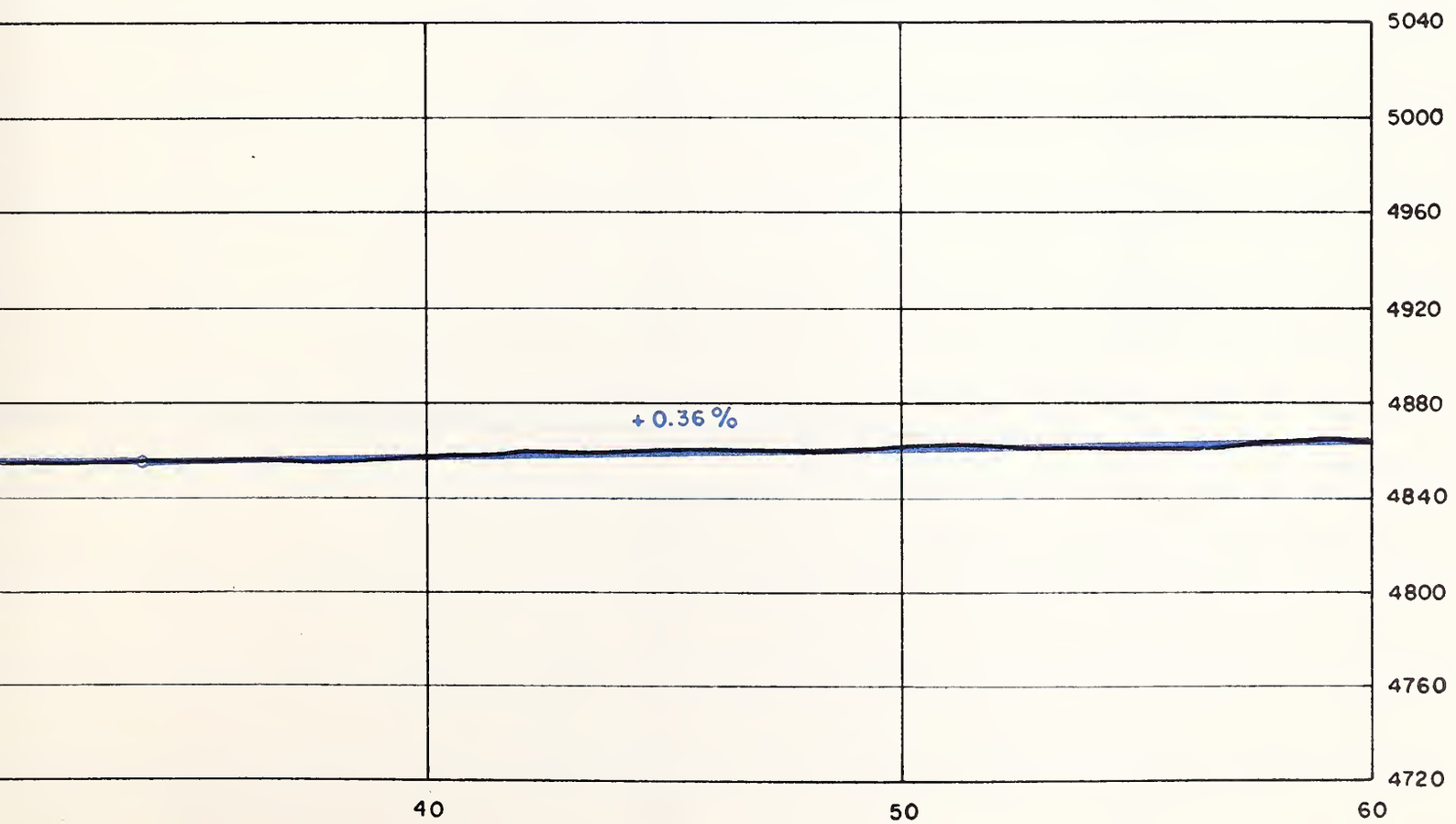
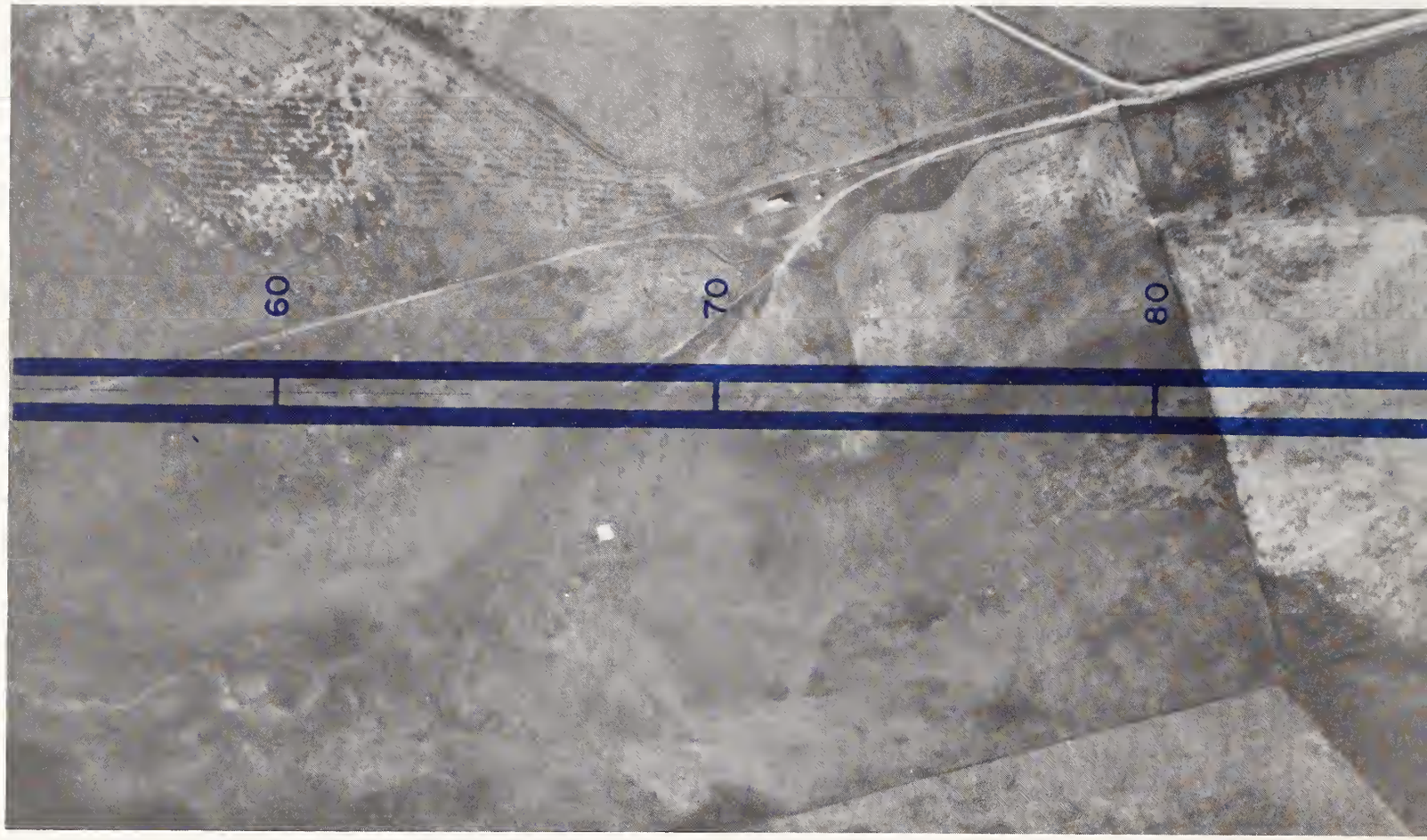


FIGURE 32



ALTERNATE 1

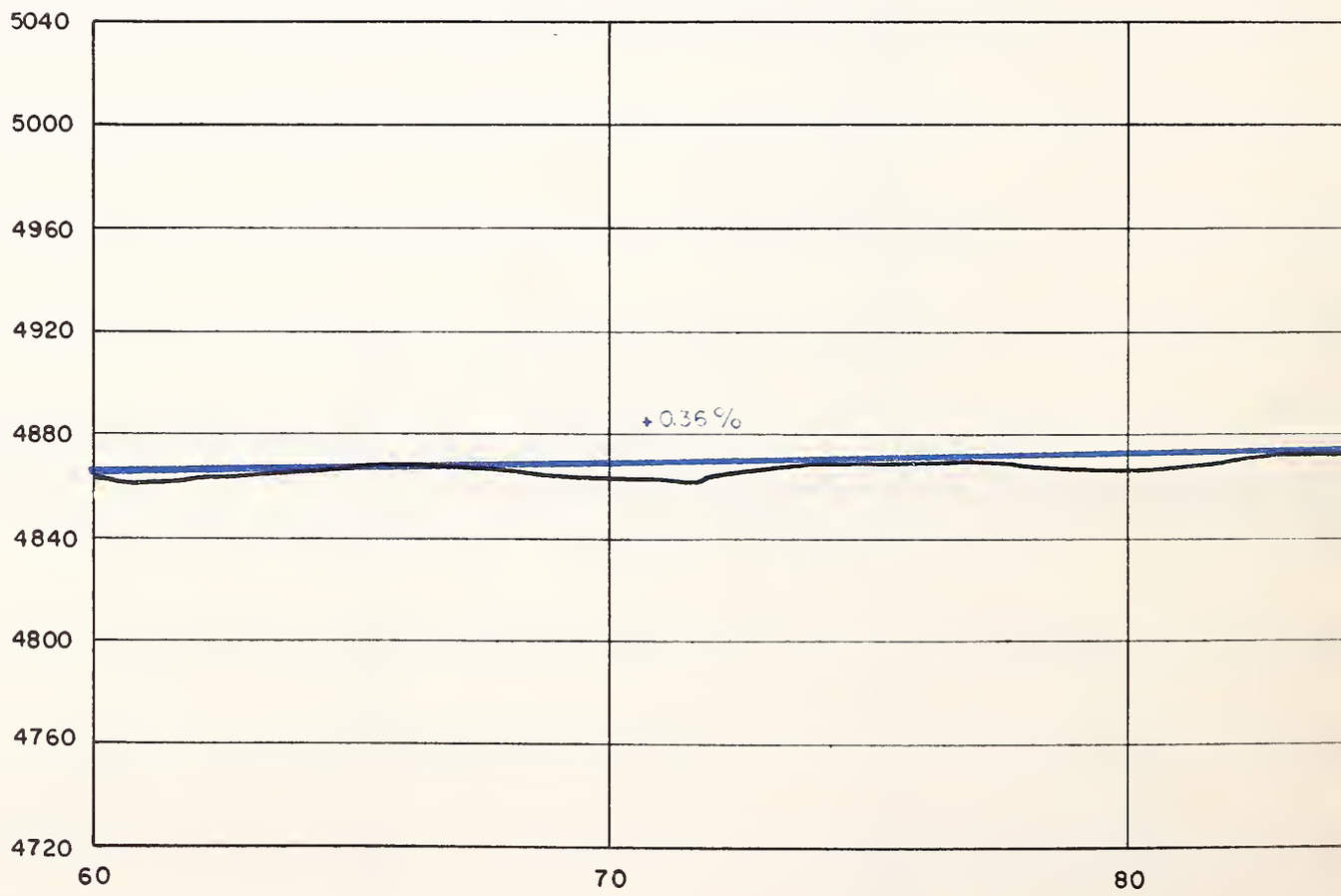
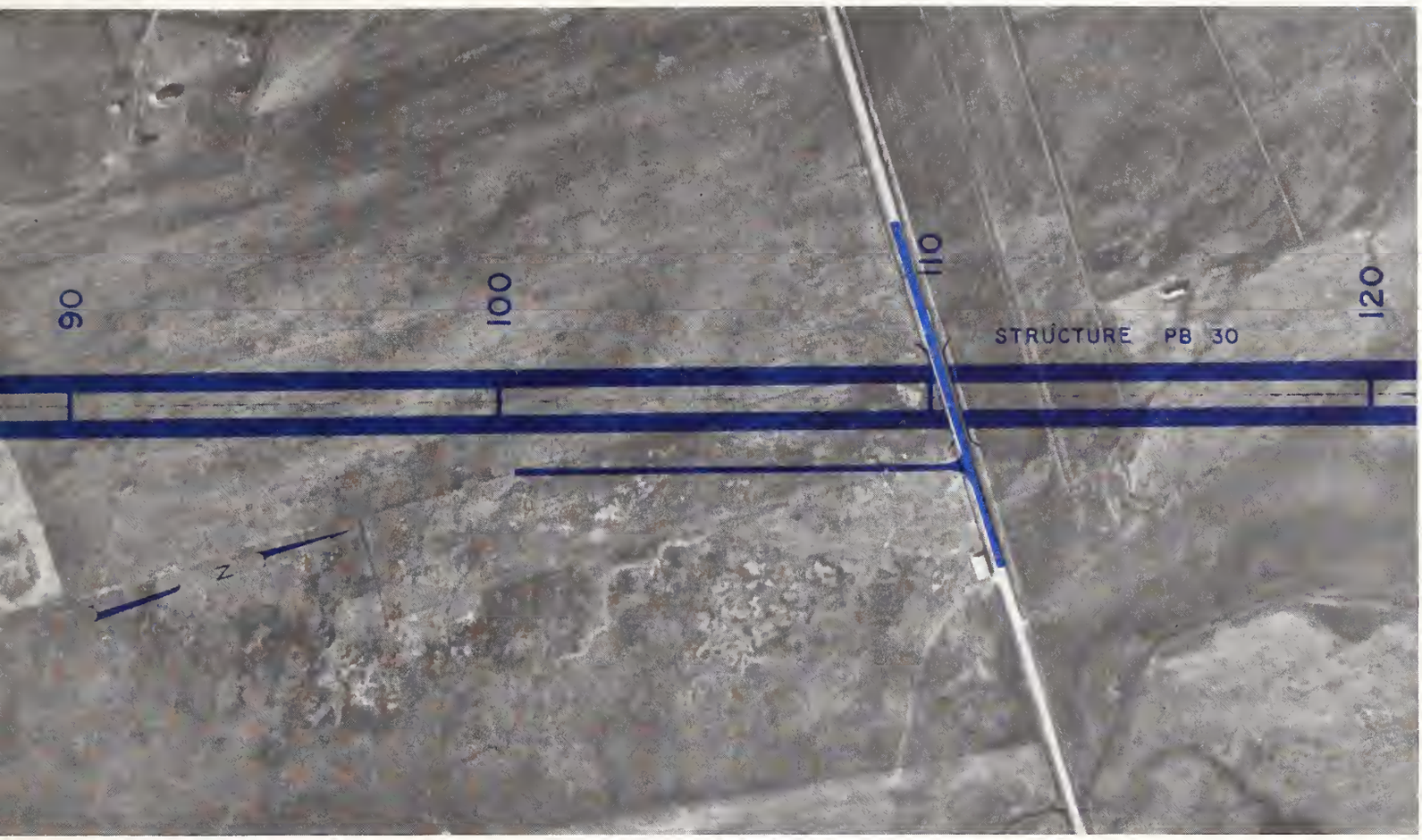


FIGURE 33



ALTERNATE 1

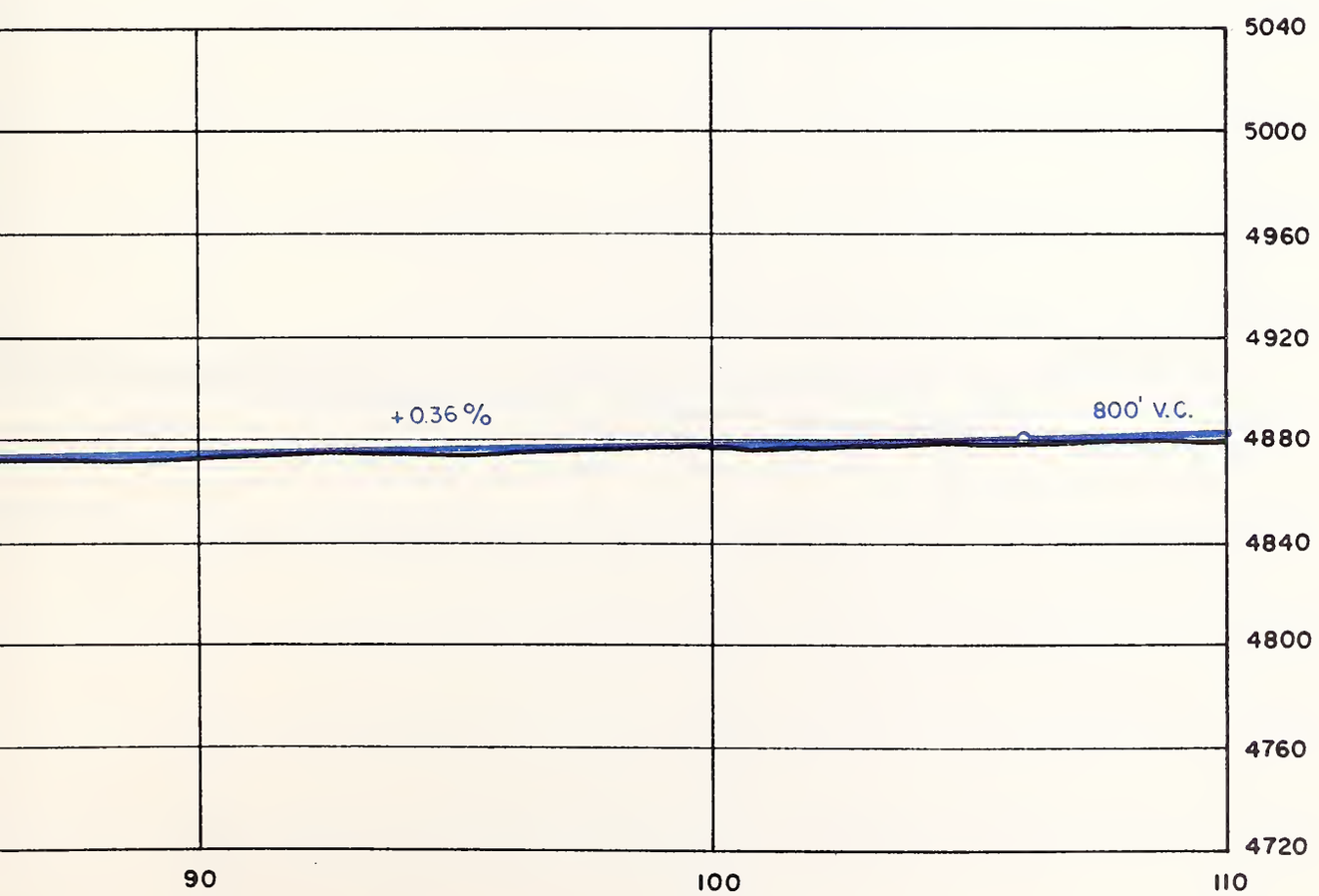
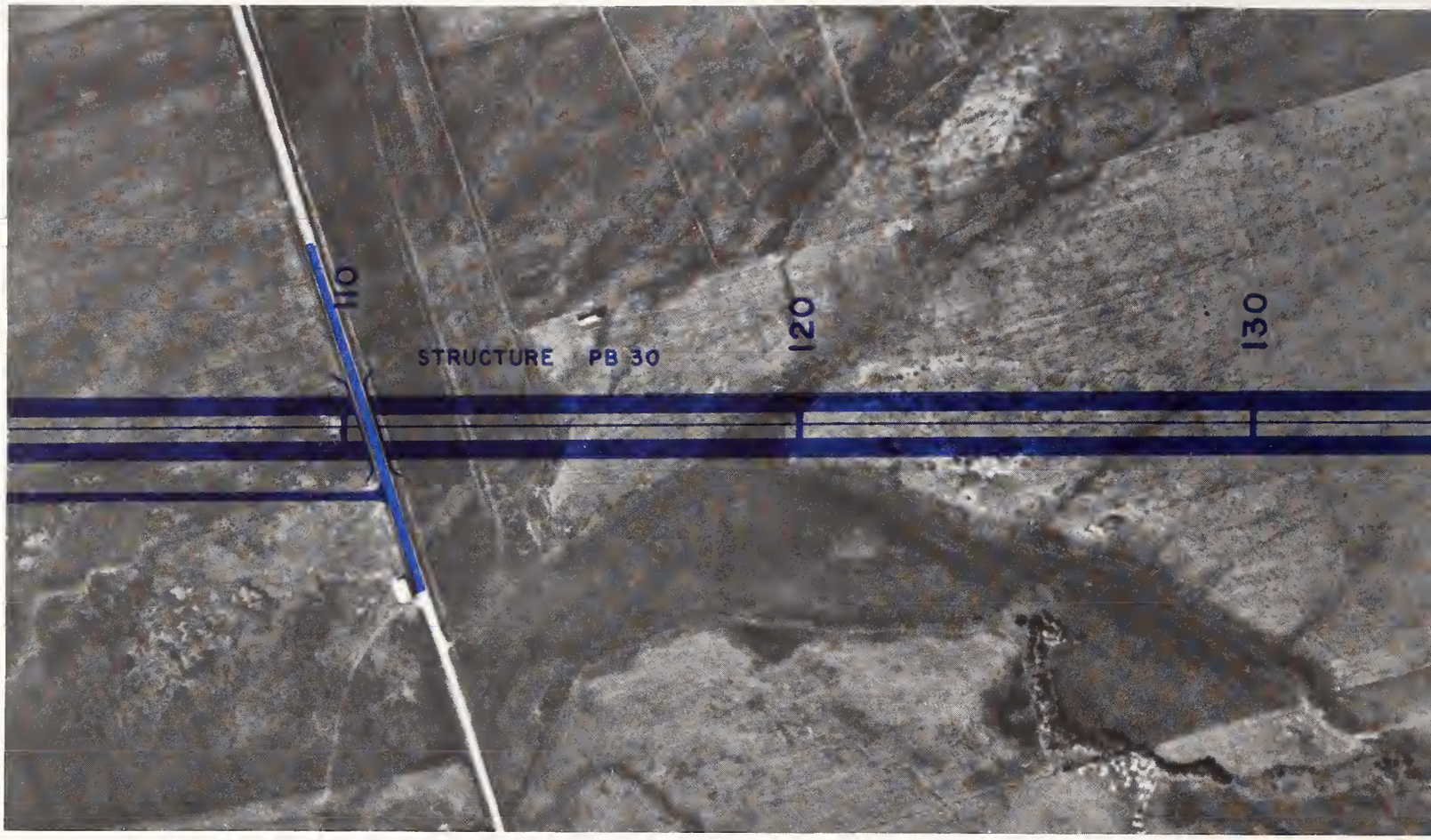
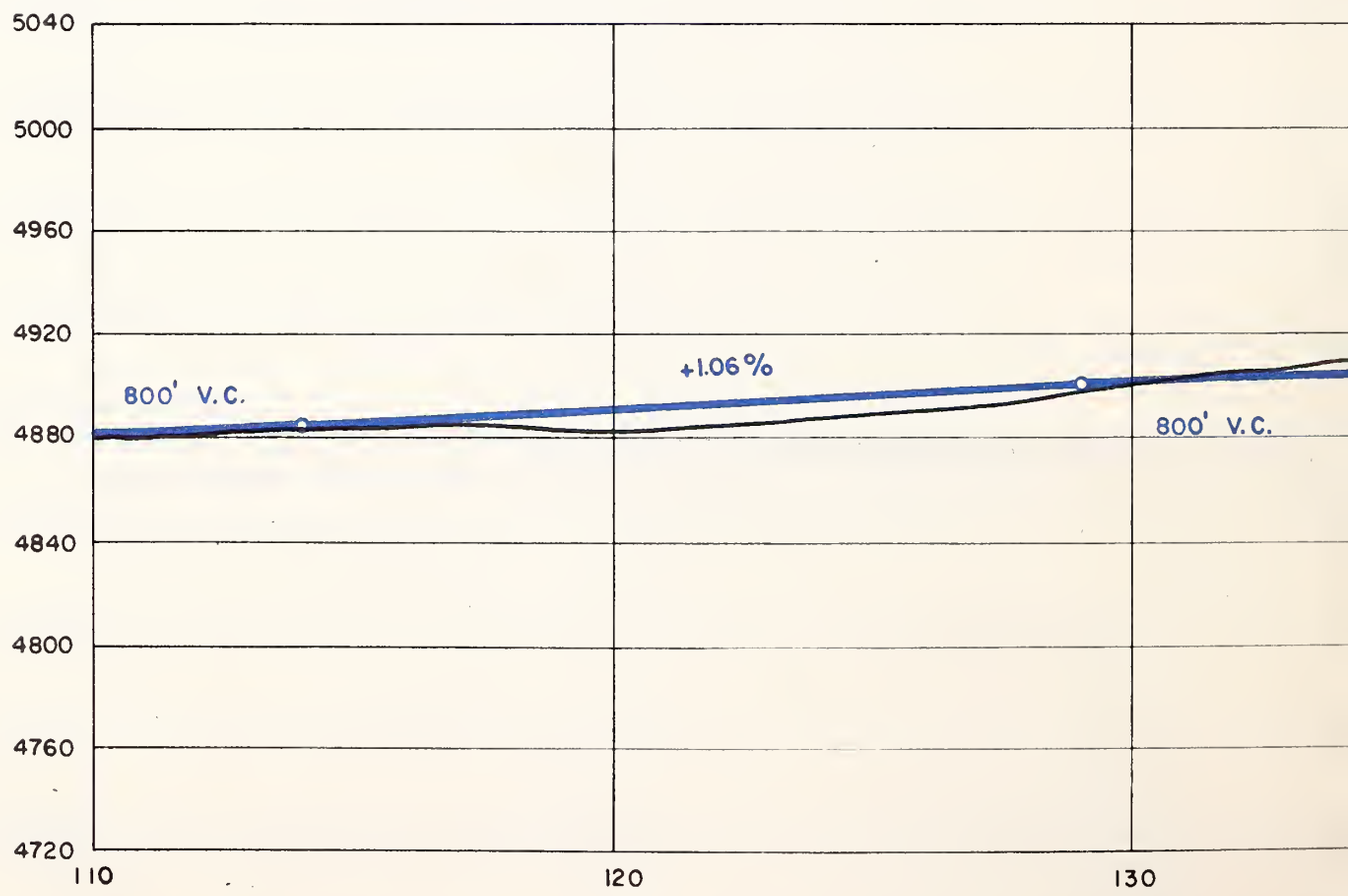
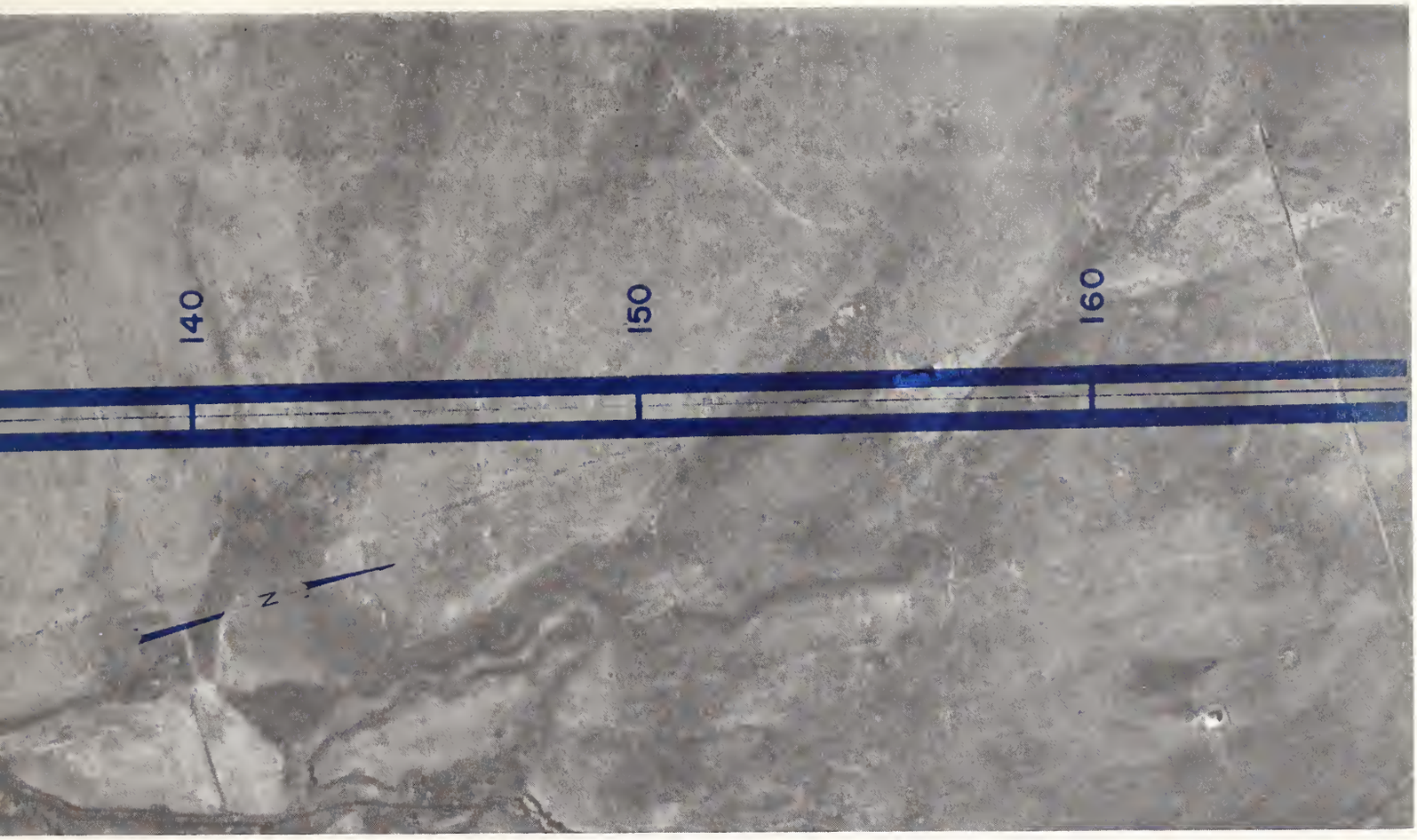


FIGURE 34



ALTERNATE 1




140
150
160
N

ALTERNATE 1

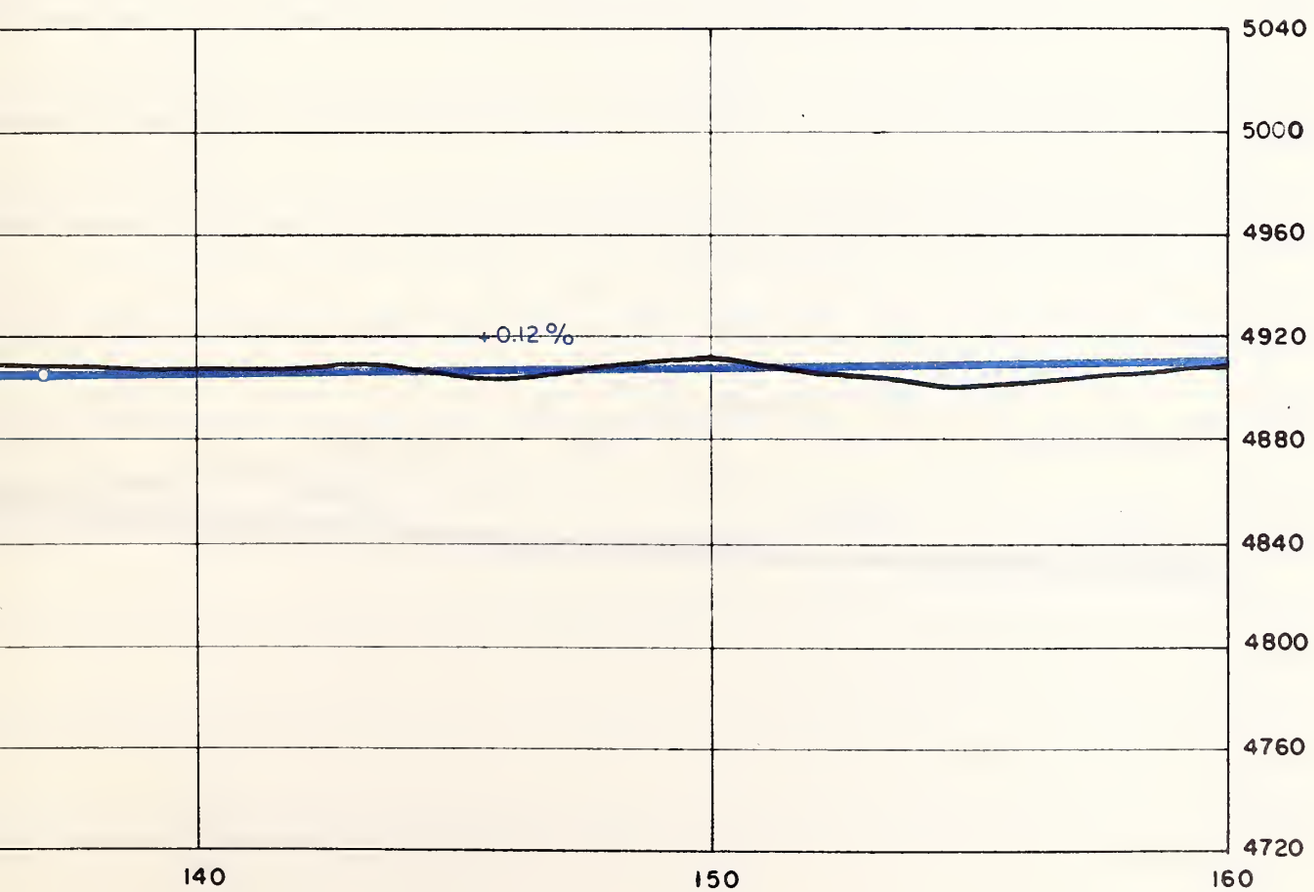
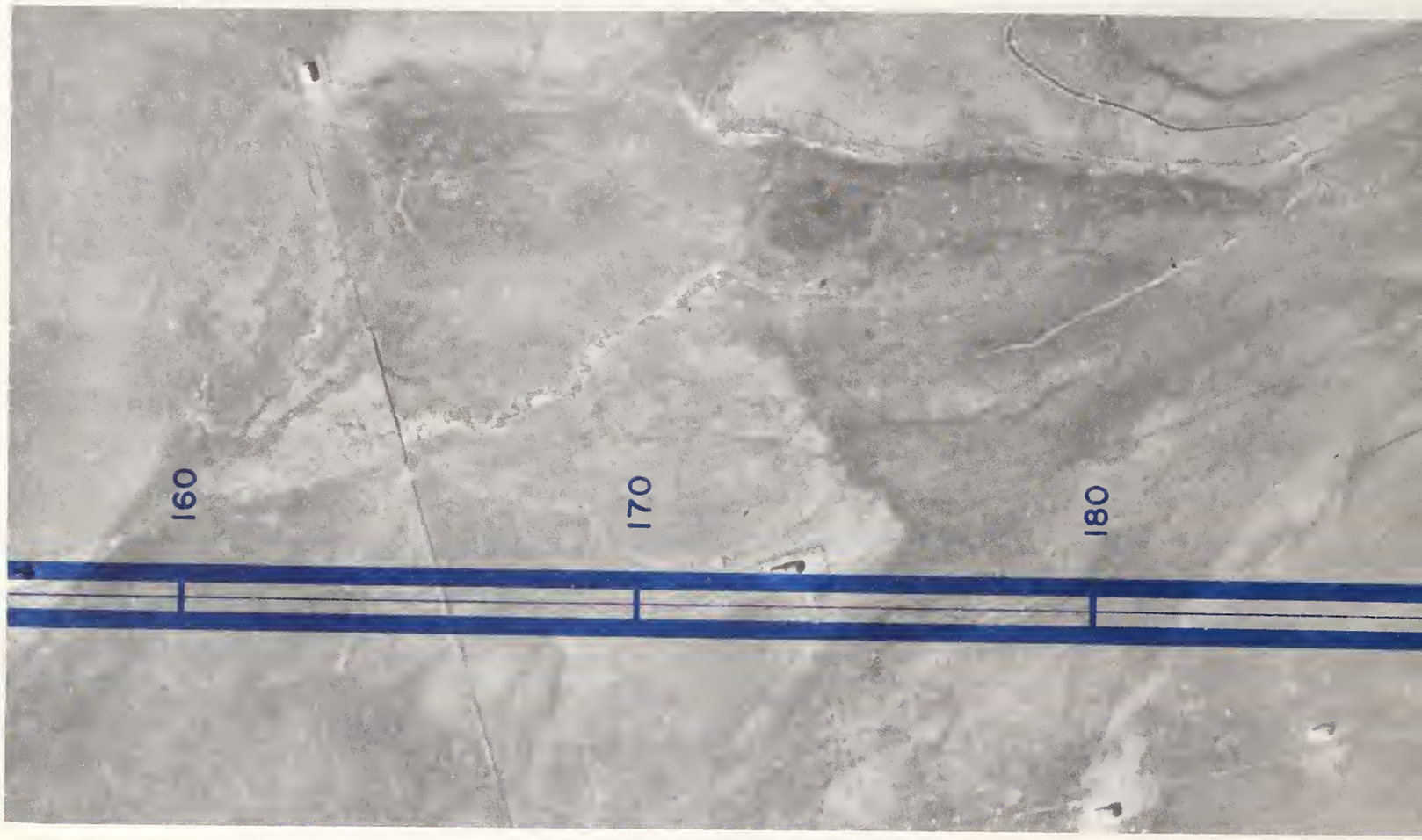
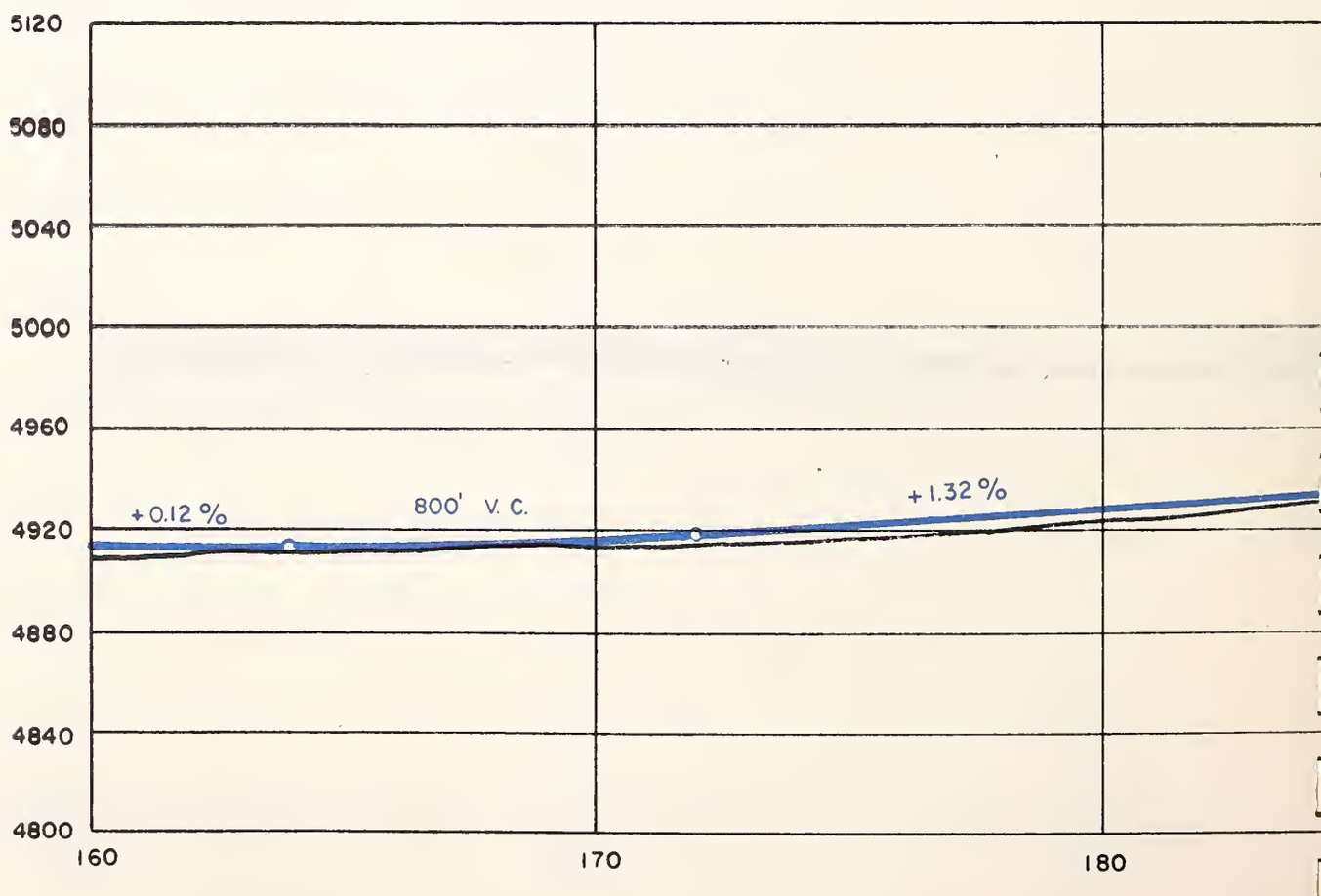

5040
5000
4960
4920
4880
4840
4800
4760
4720
+0.12%
140
150
160

FIGURE 36



ALTERNATE 1



N
190
200
STA. 210+00 BK.
END ALT 1
BEGIN ALT. 3
STA. 170+00 N.B. AH.
STA. 170+42 S.B. AH
Dc = 30° 30'
VEHICULAR
UNDERPASS

ALTERNATE 1

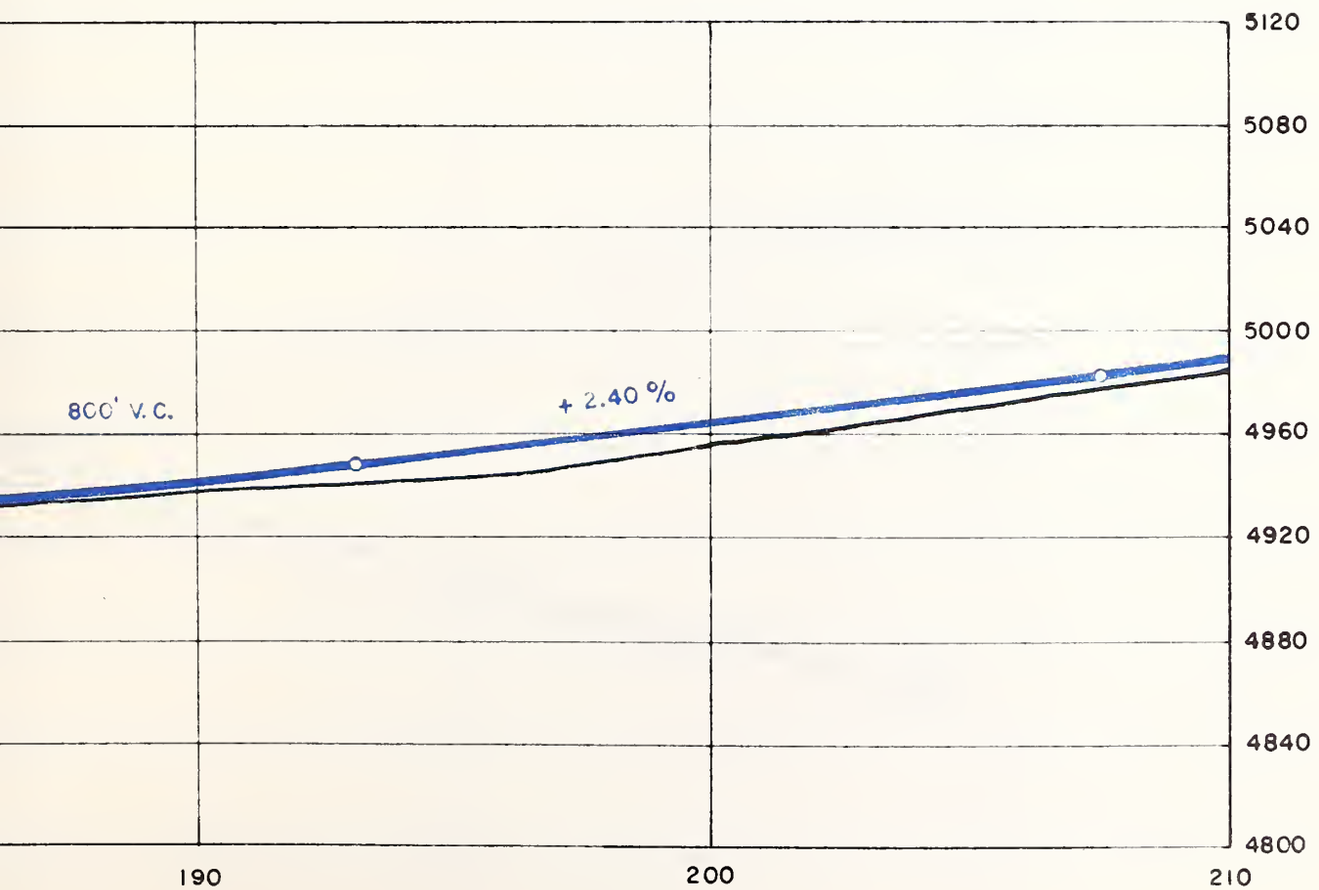
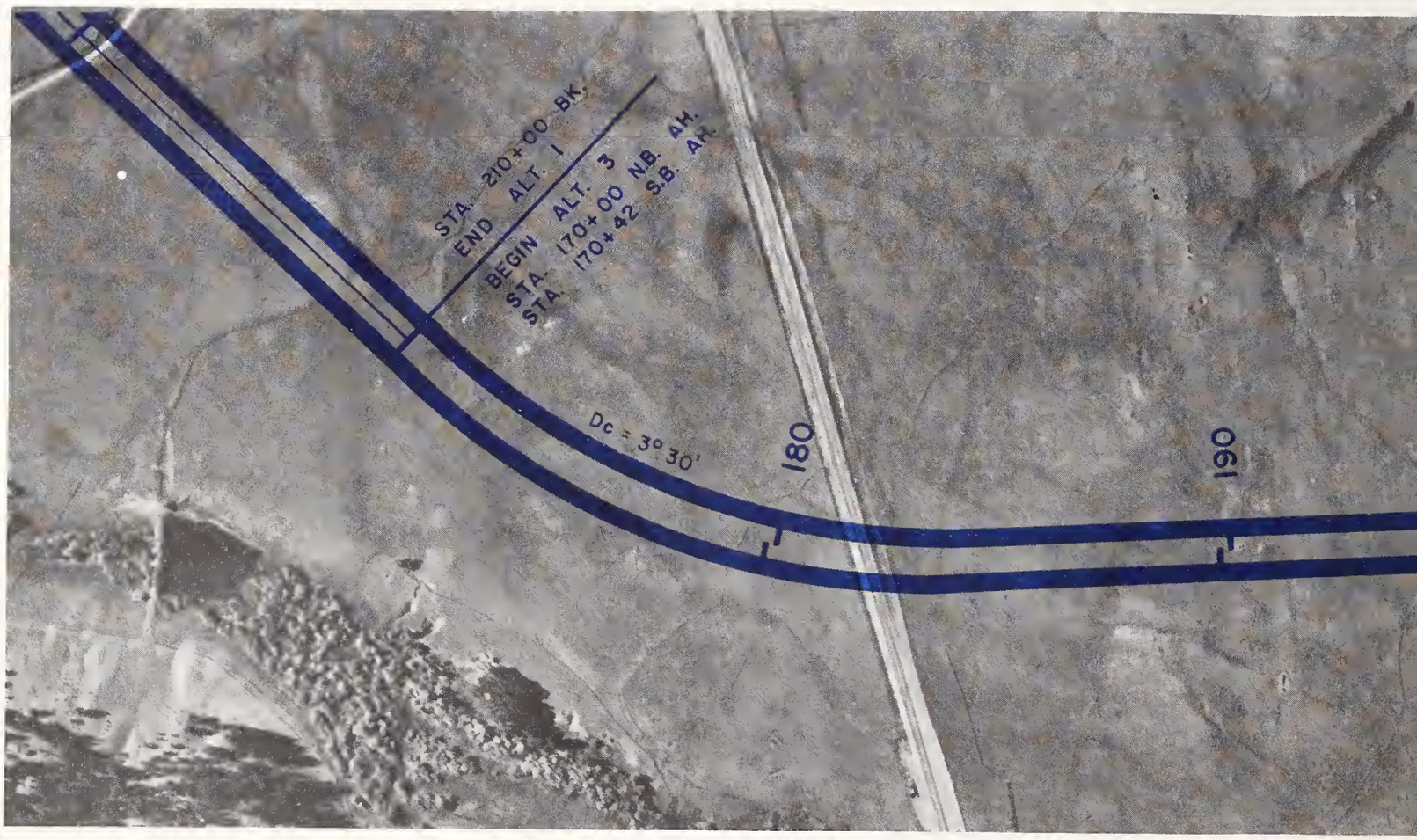
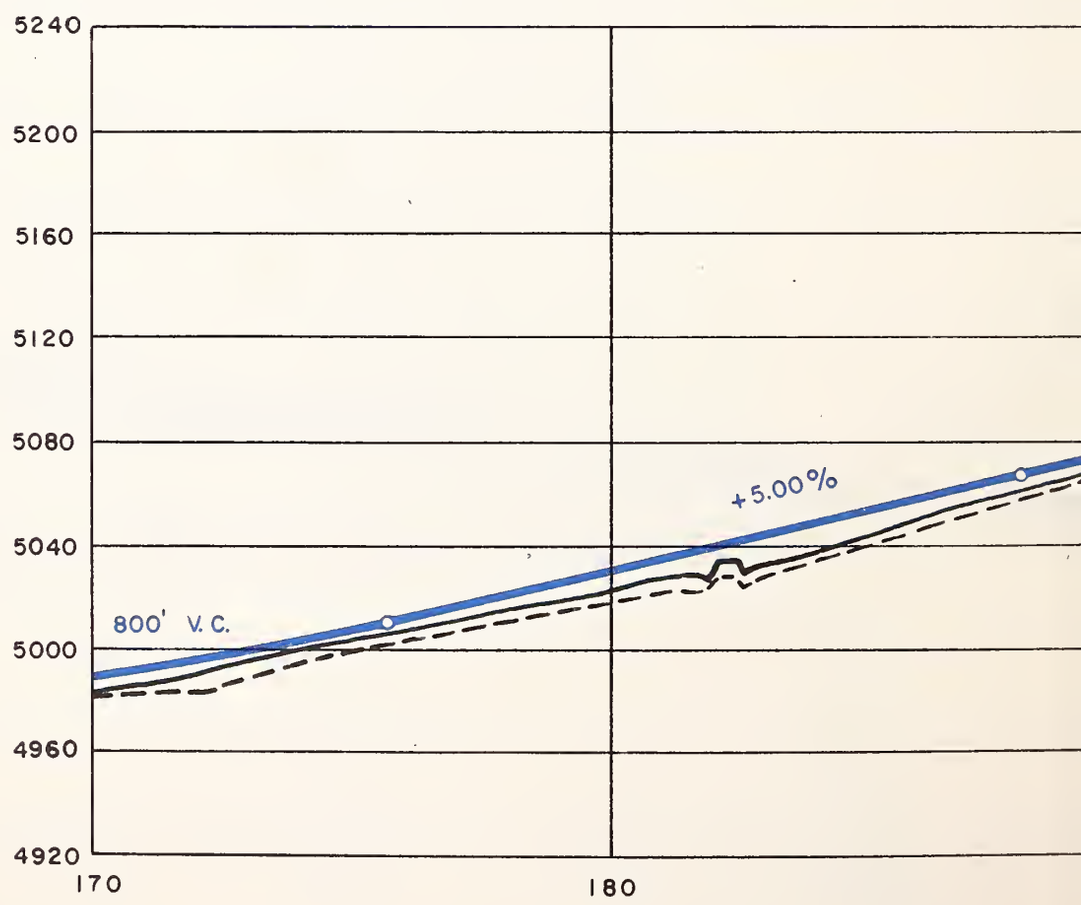
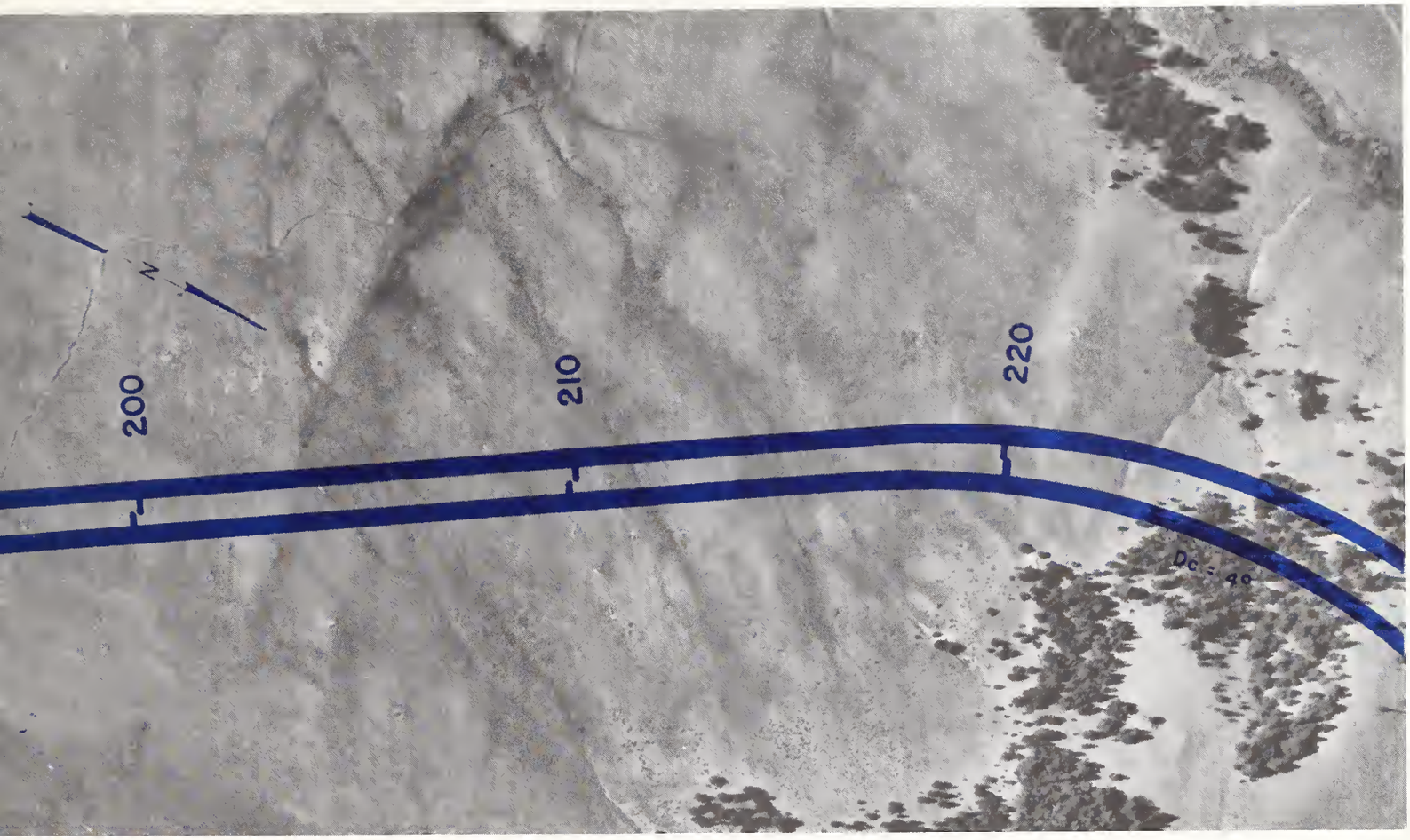

5120
5080
5040
5000
4960
4920
4880
4840
4800
800' V.C.
+ 2.40 %
190
200
210

FIGURE 38



ALTERNATE 3




N
200
210
220
Dc = 4°

ALTERNATE 3

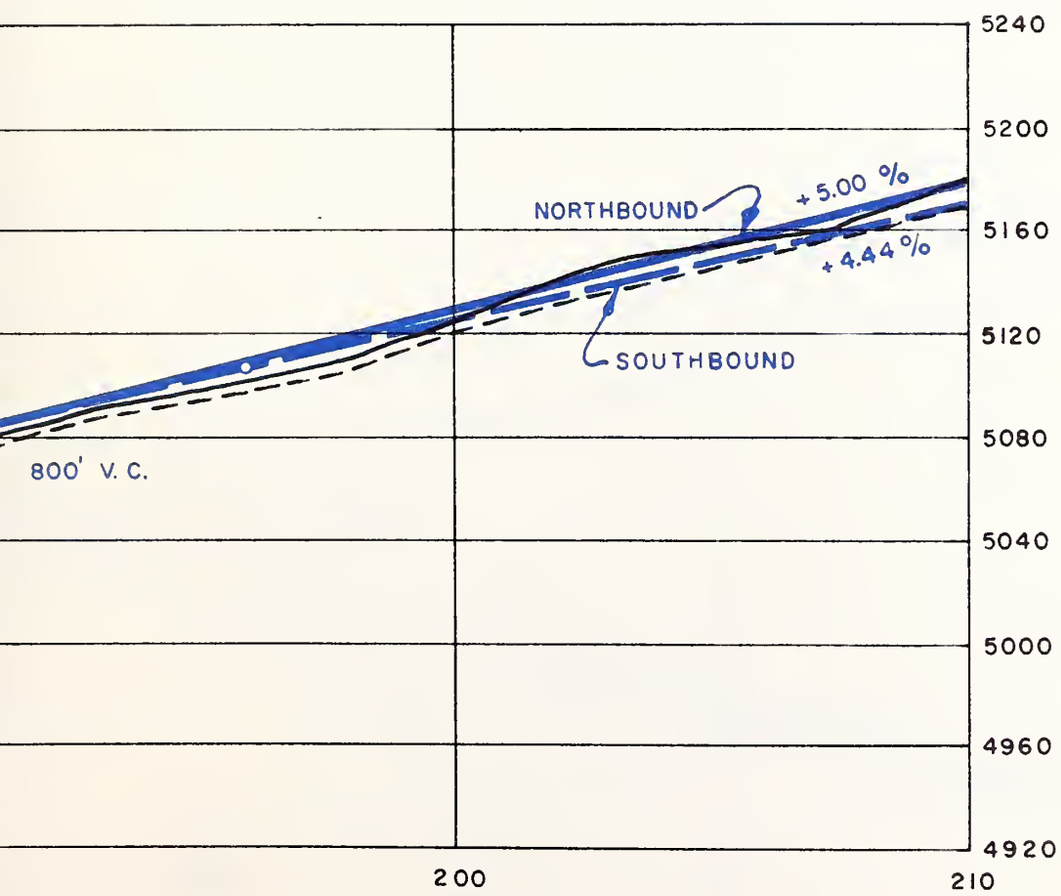
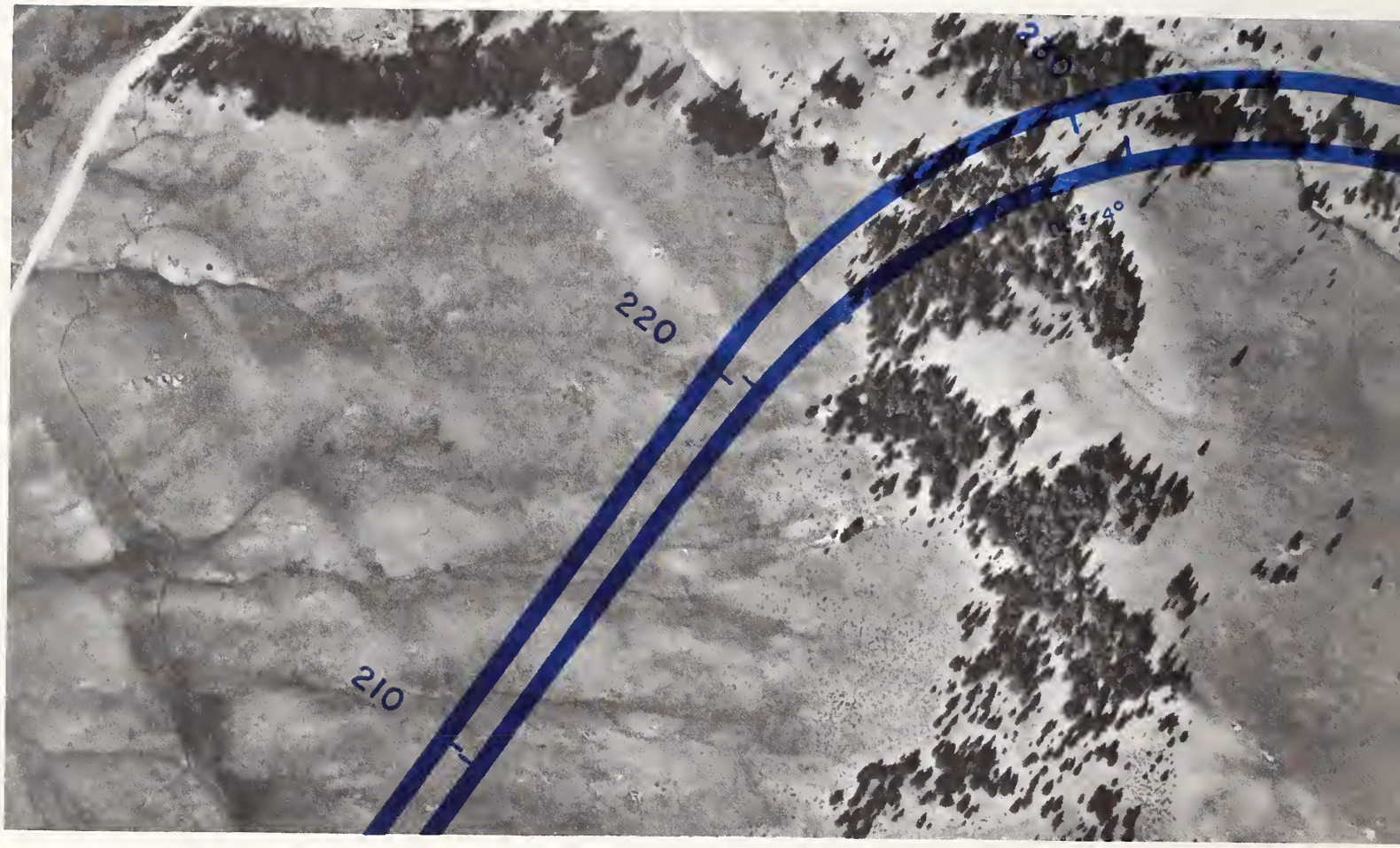
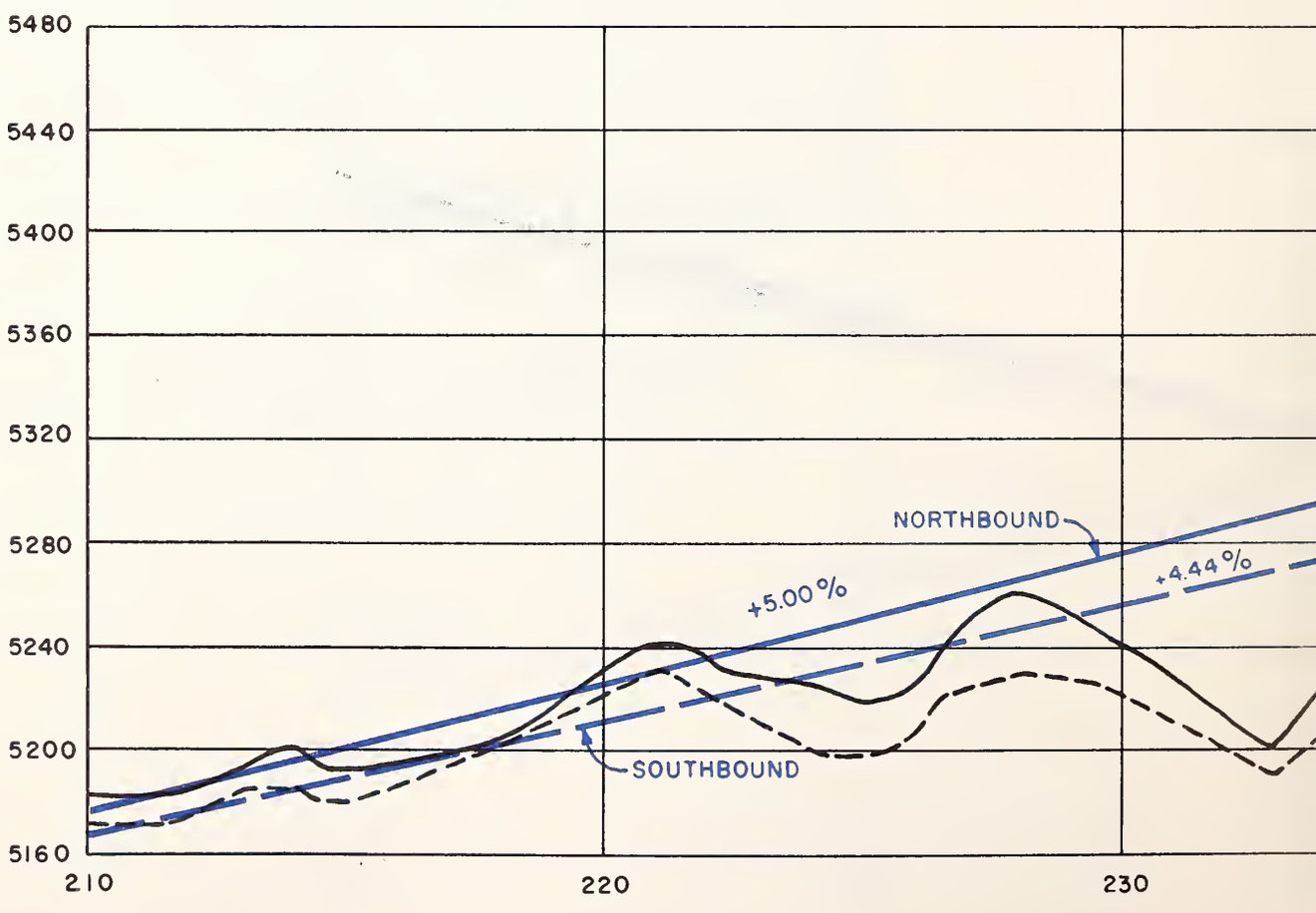
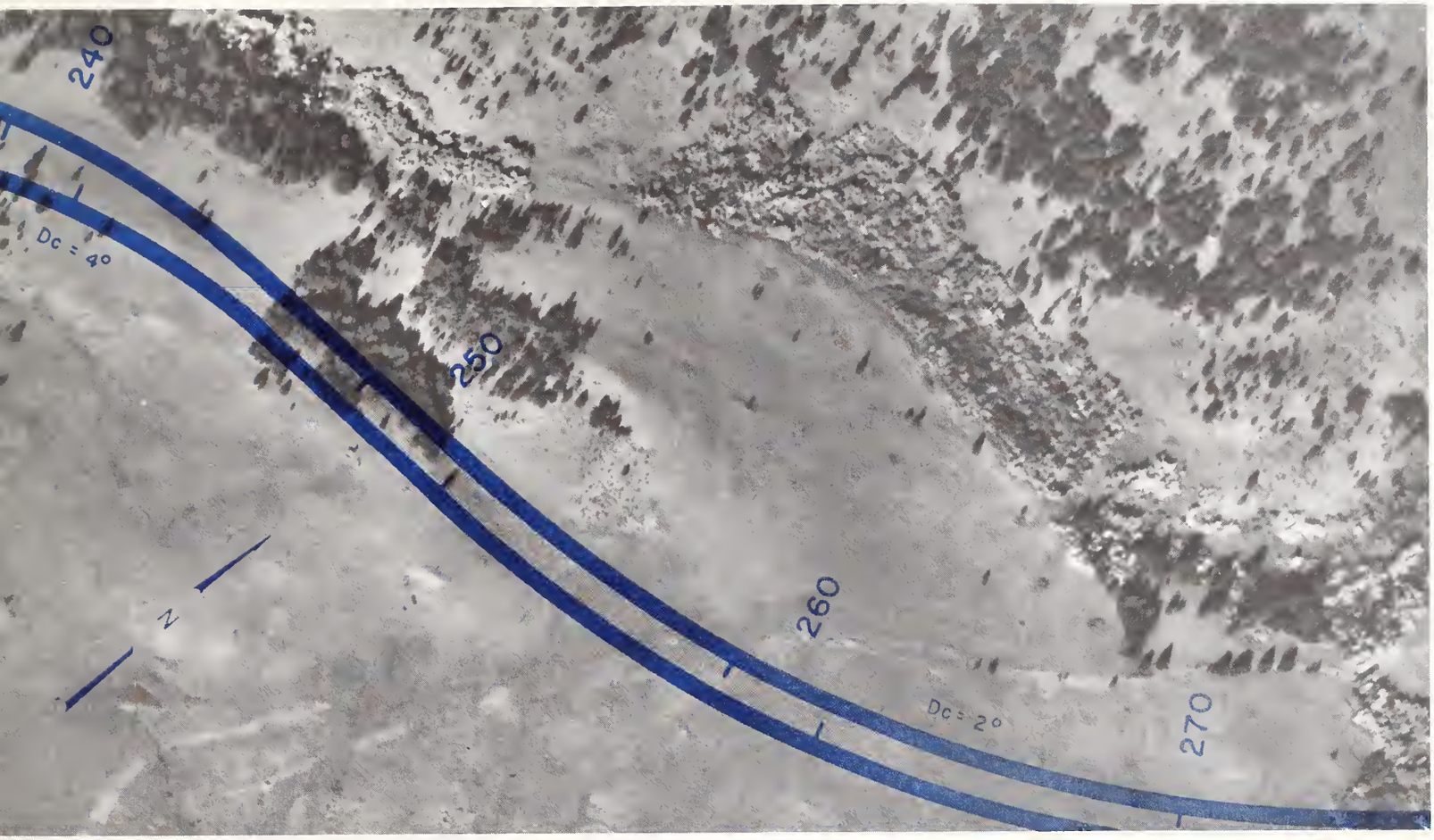

5240
5200
5160
5120
5080
5040
5000
4960
4920
NORTHBOUND
+5.00 %
+4.44 %
SOUTHBOUND
800' V. C.
200
210

FIGURE 40



ALTERNATE 3




240
Dc = 4°
250
260
Dc = 2°
270
N

ALTERNATE 3

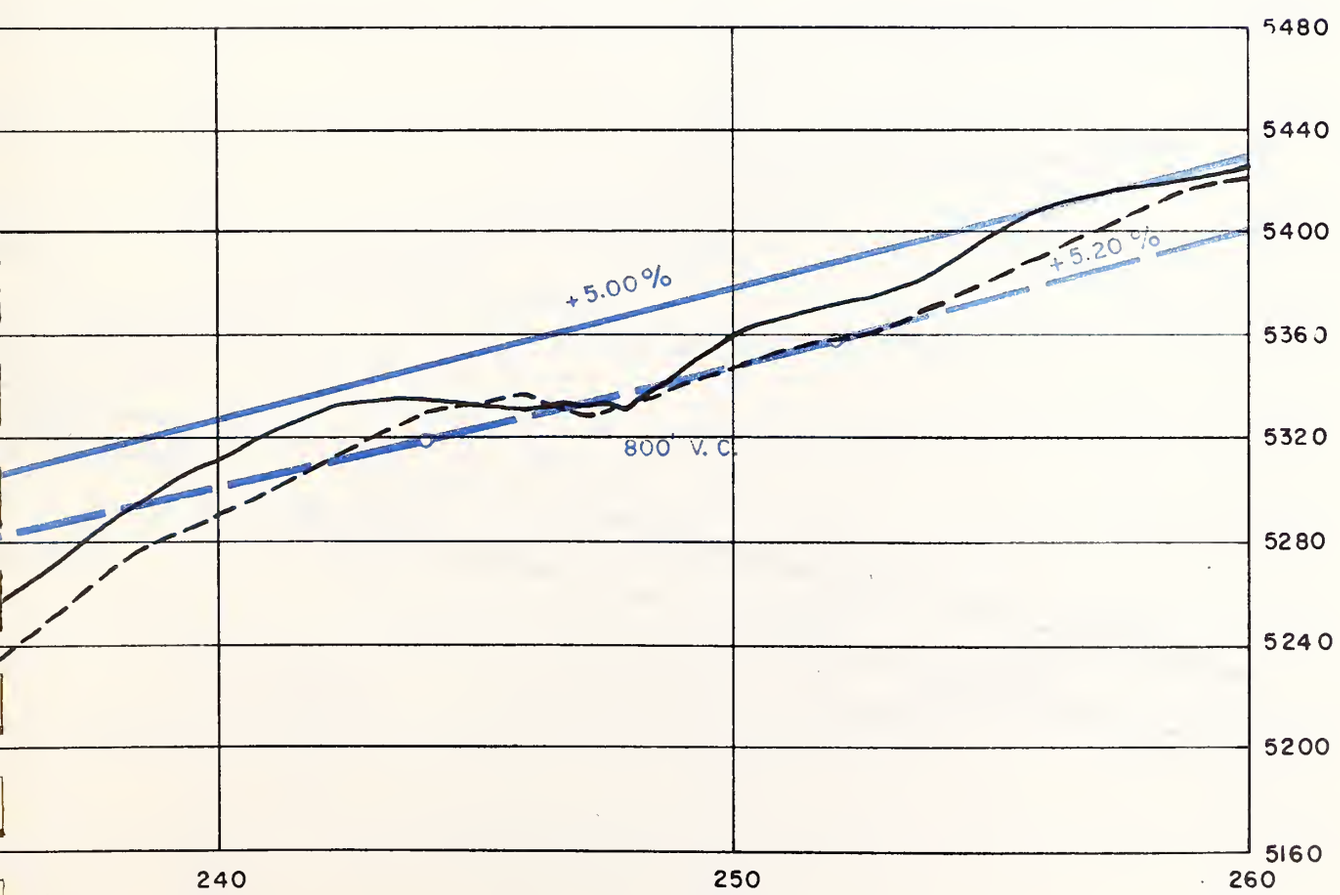
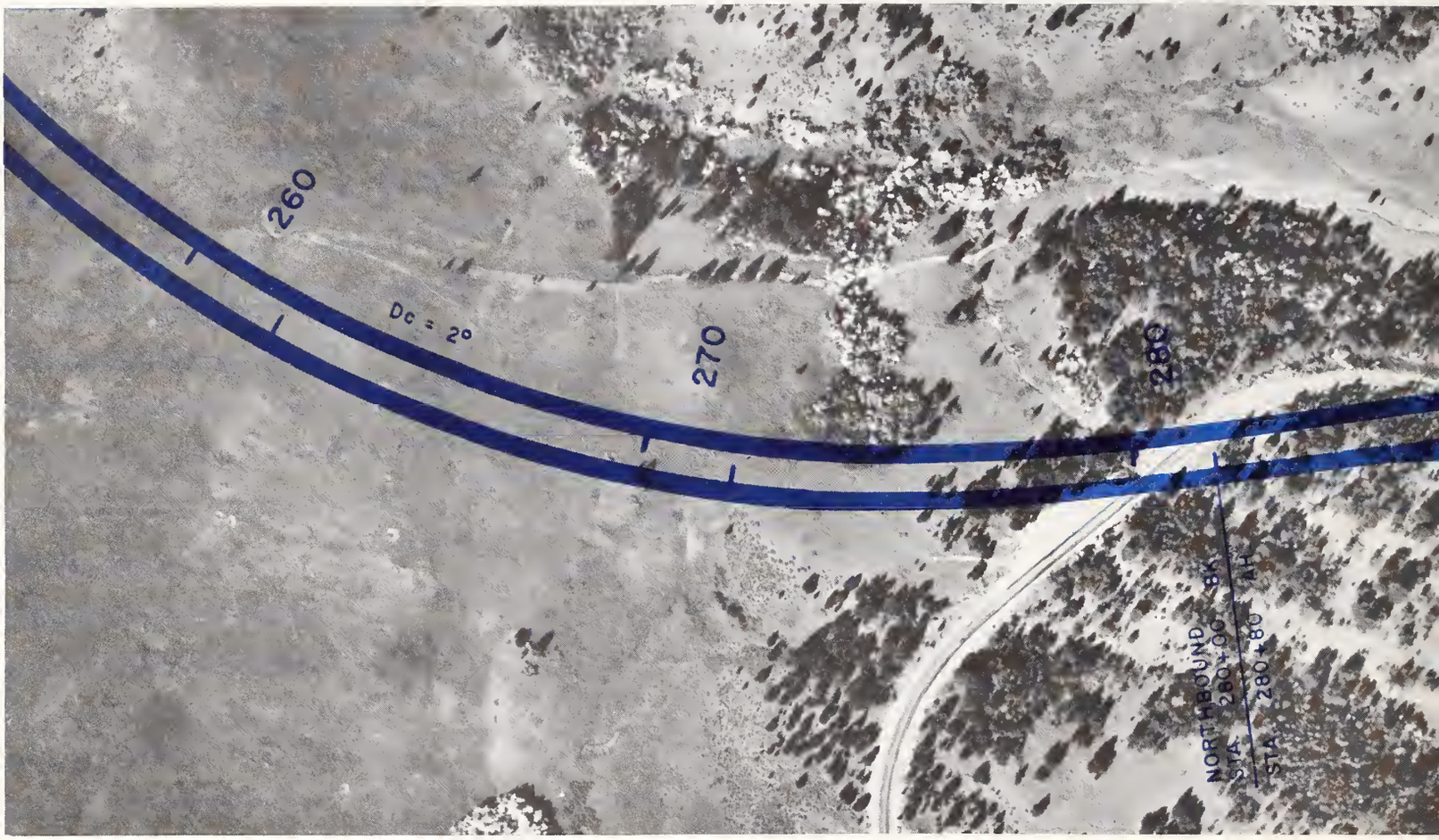

5480
5440
5400
5360
5320
5280
5240
5200
5160
+5.00%
+5.20%
800' V. C.
240
250
260

FIGURE 42



ALTERNATE 3

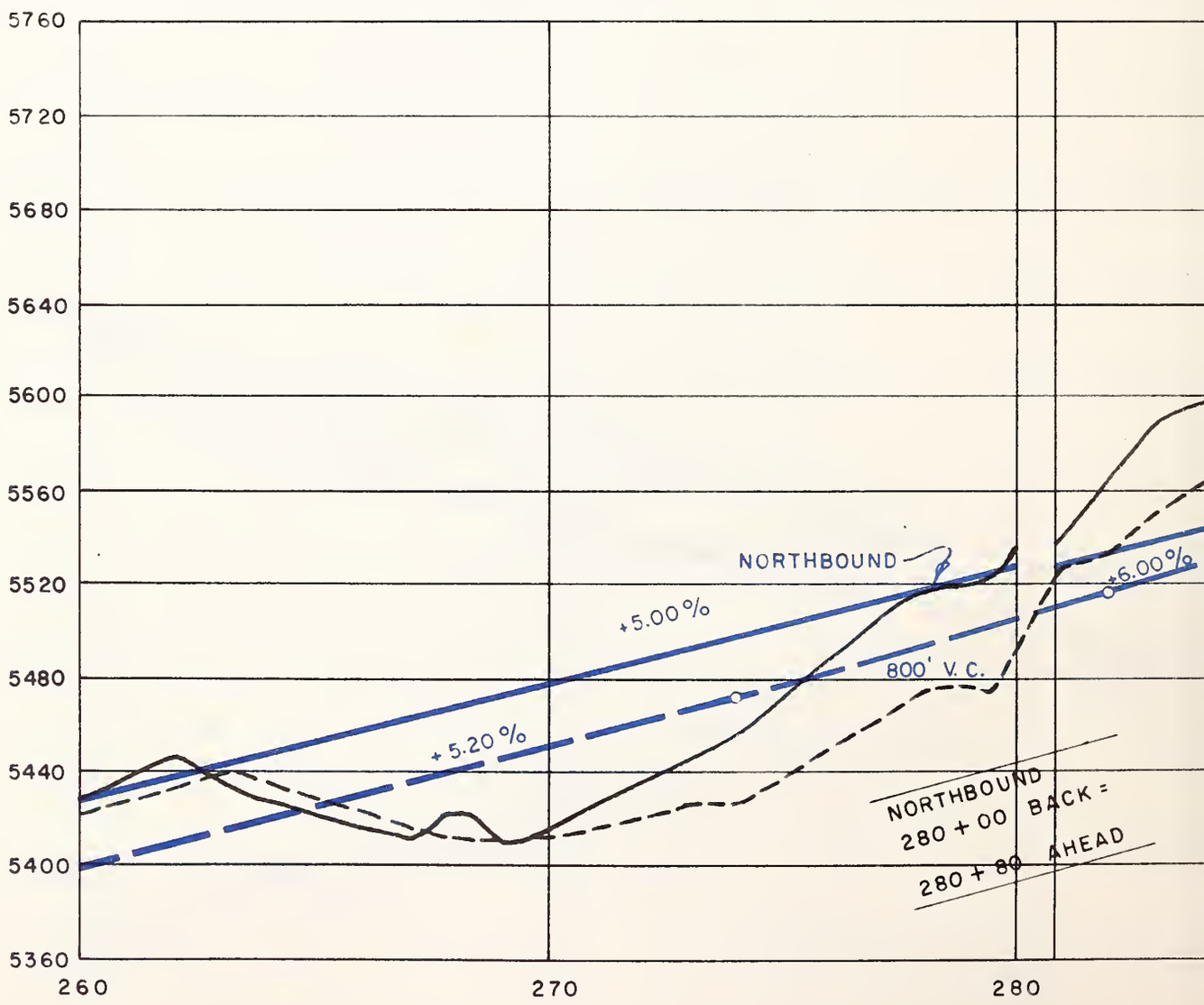


FIGURE 43

ALTERNATE 3

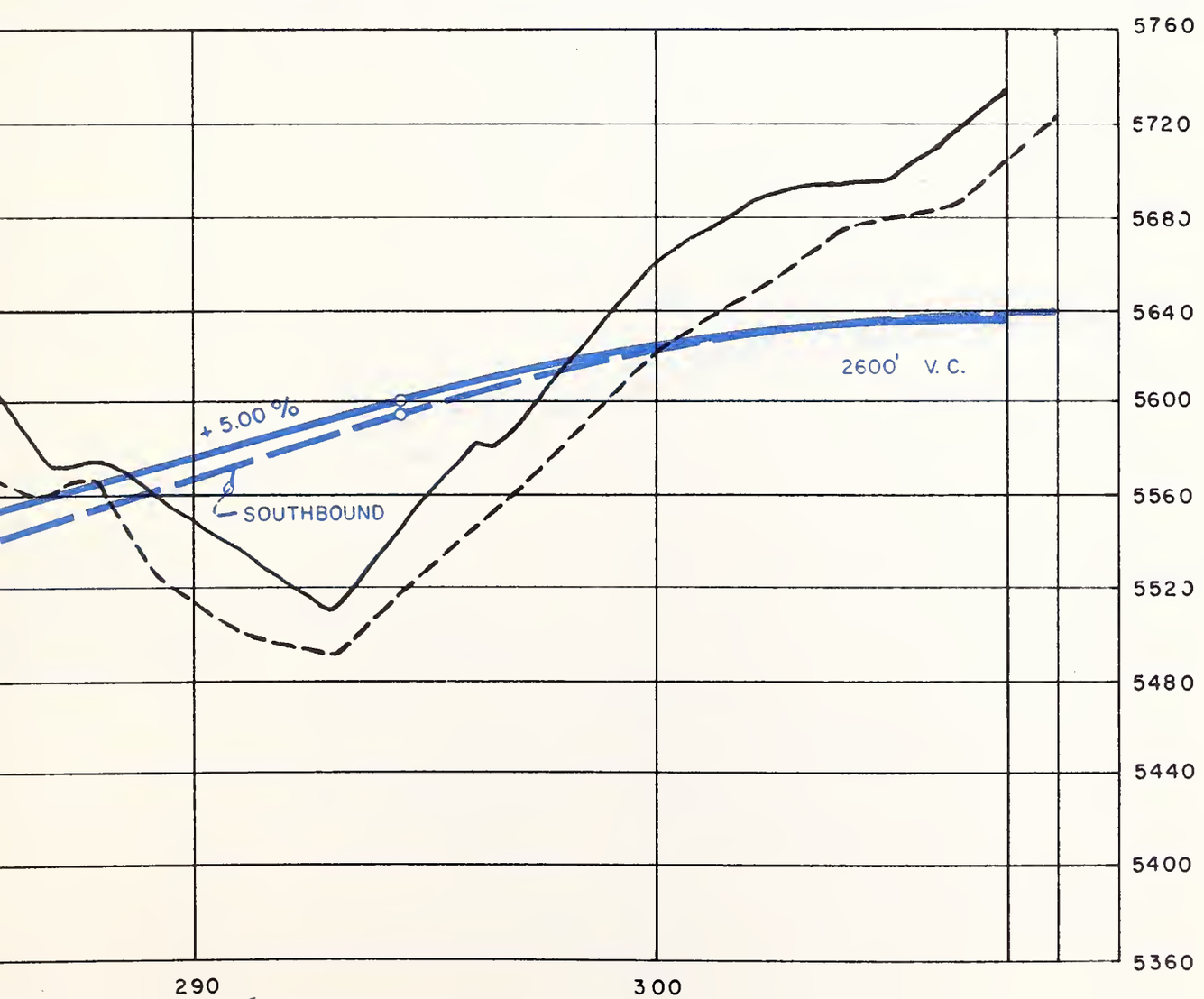
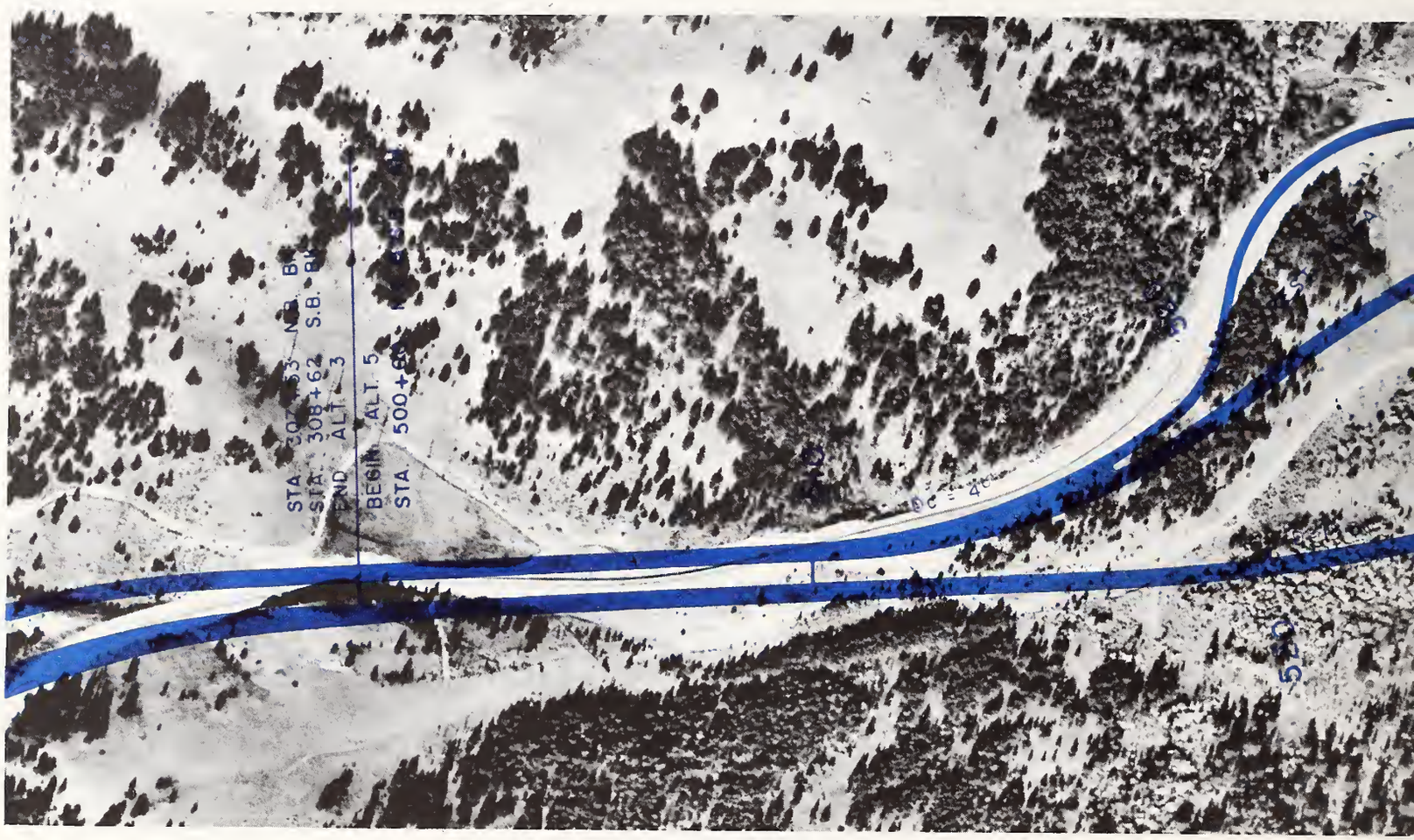
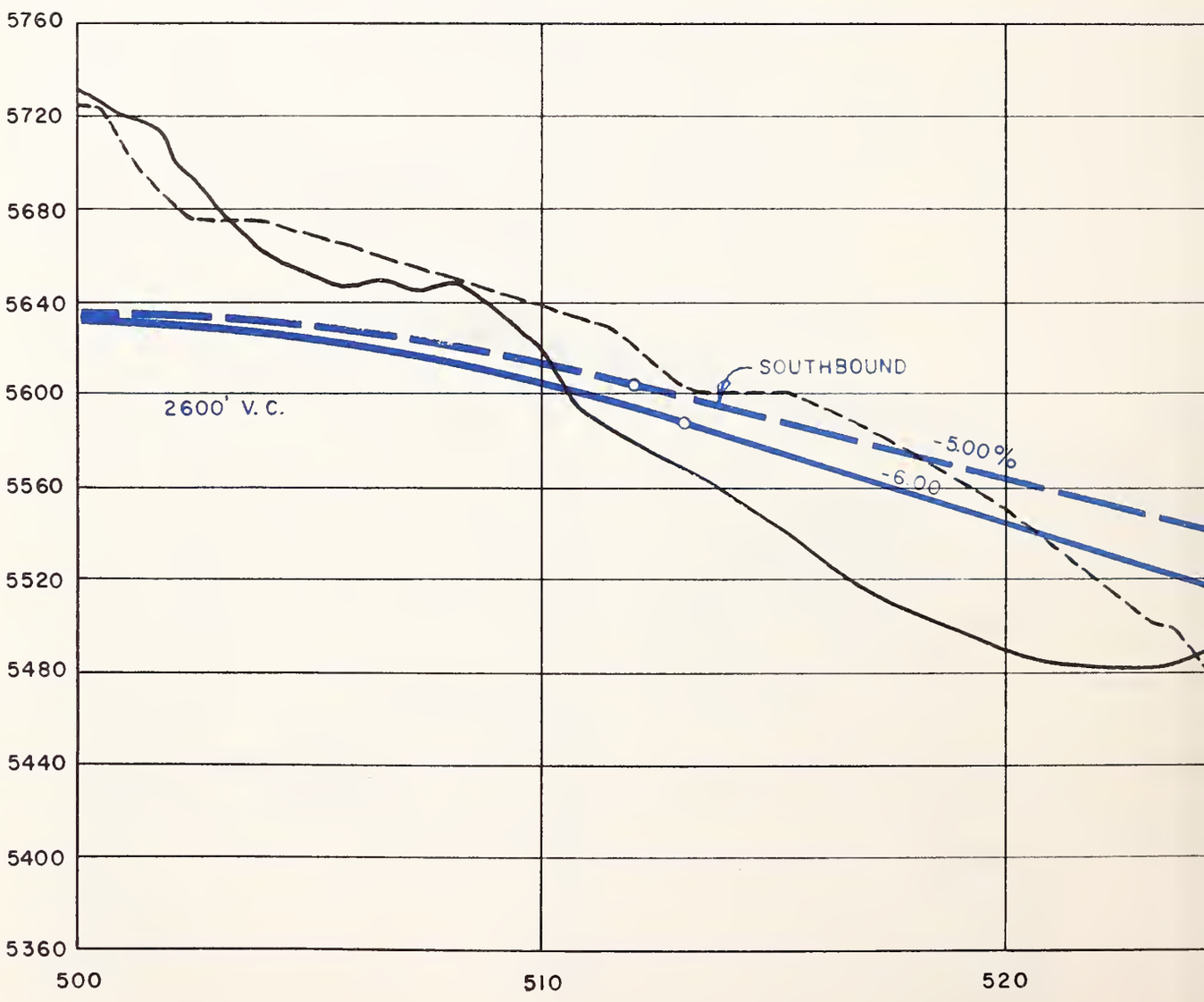
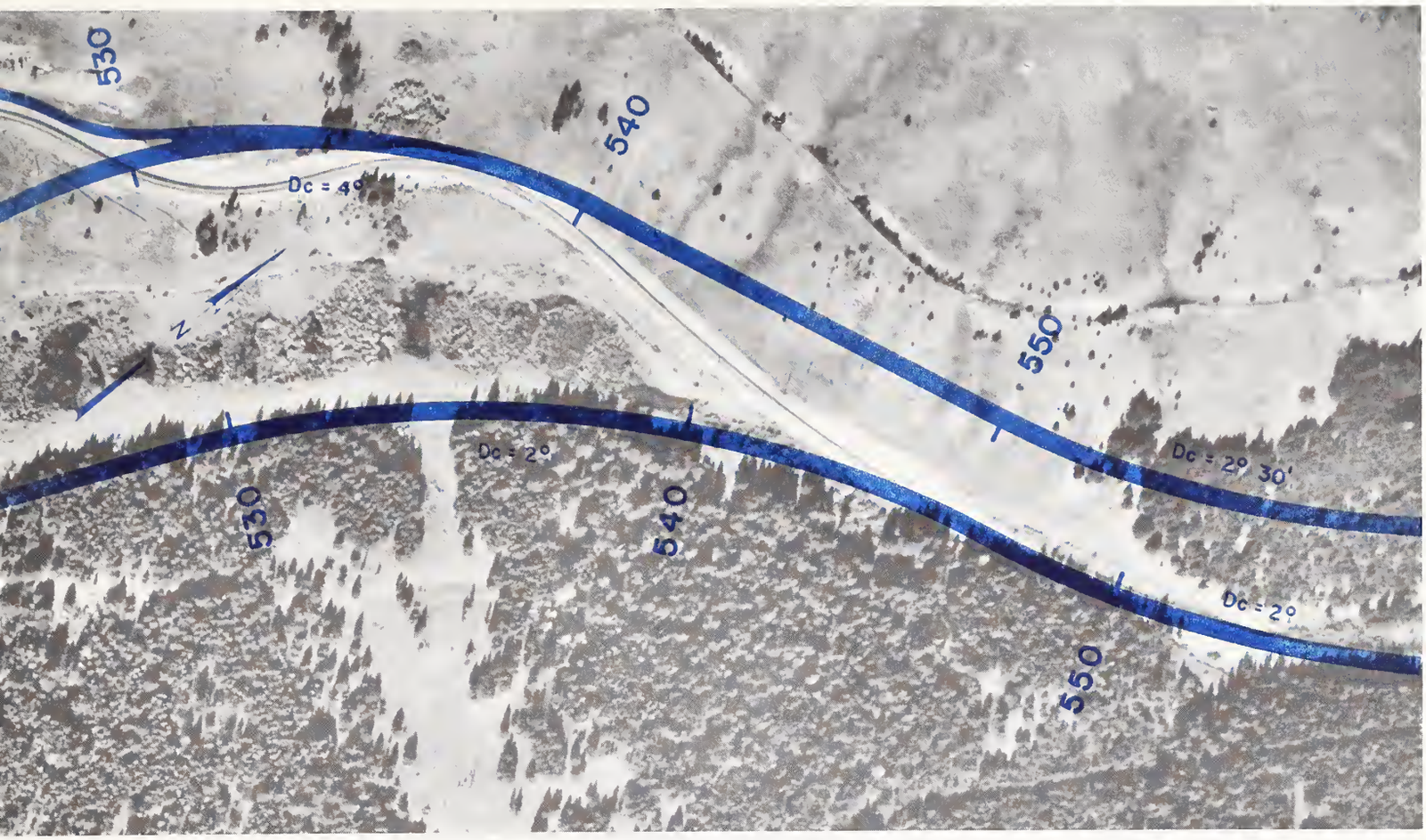


FIGURE 44



ALTERNATE 5




530
540
550
Dc = 4°
N
Dc = 2°
530
540
Dc = 2° 30'
Dc = 2°
550

ALTERNATE 5

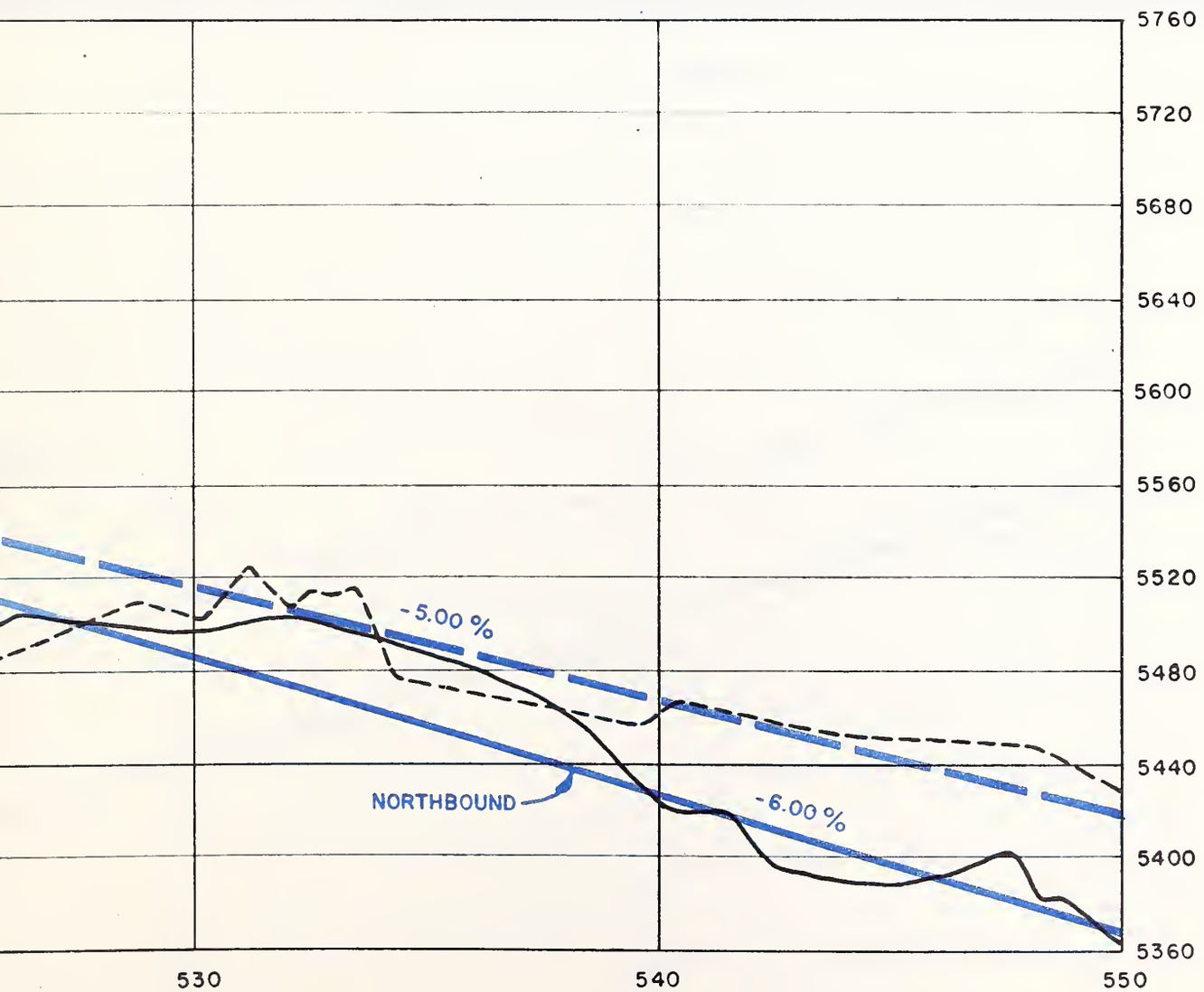
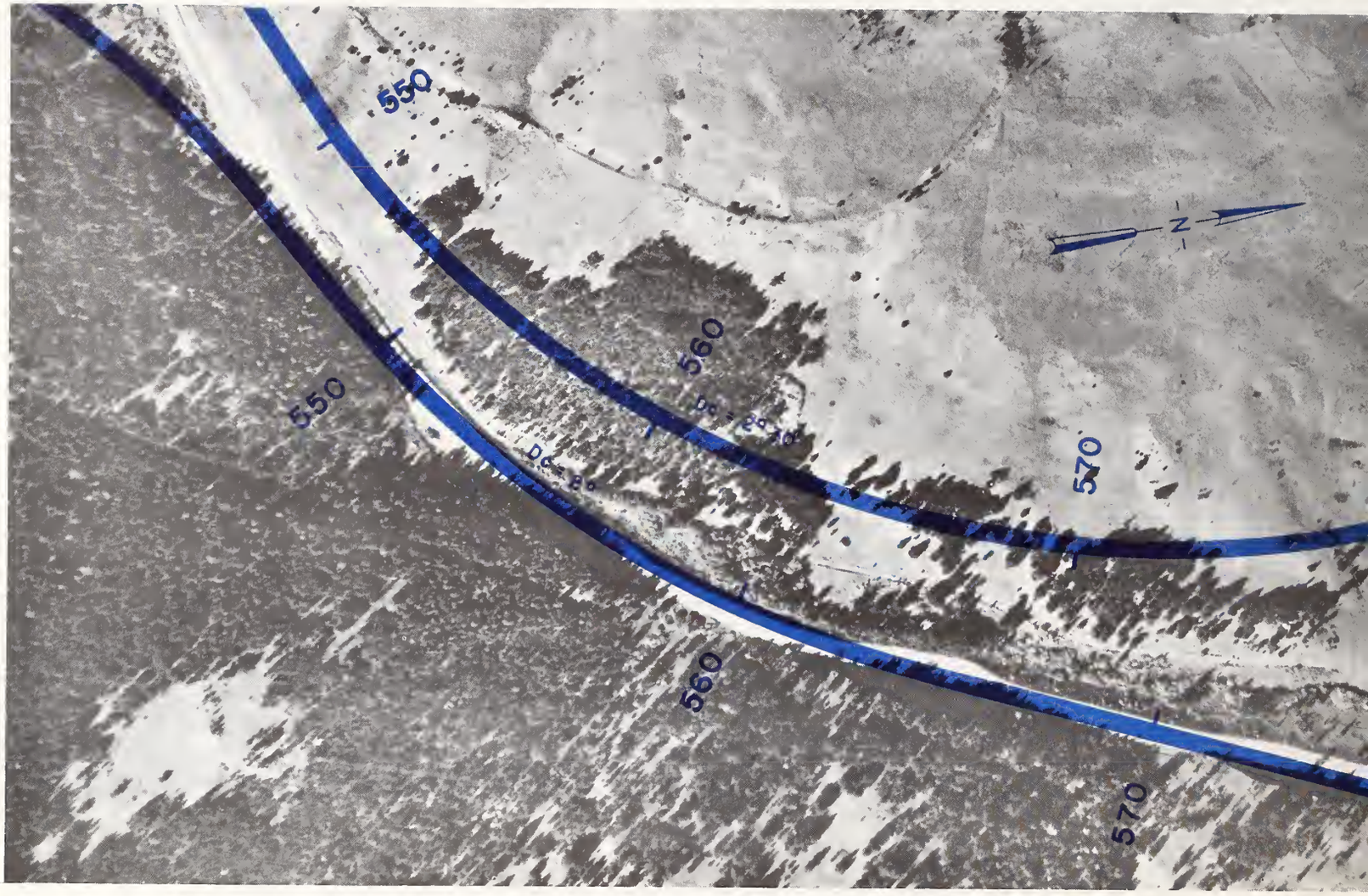

5760
5720
5680
5640
5600
5560
5520
5480
5440
5400
5360
-5.00 %
NORTHBOUND
-6.00 %
530
540
550

FIGURE 46



ALTERNATE 5

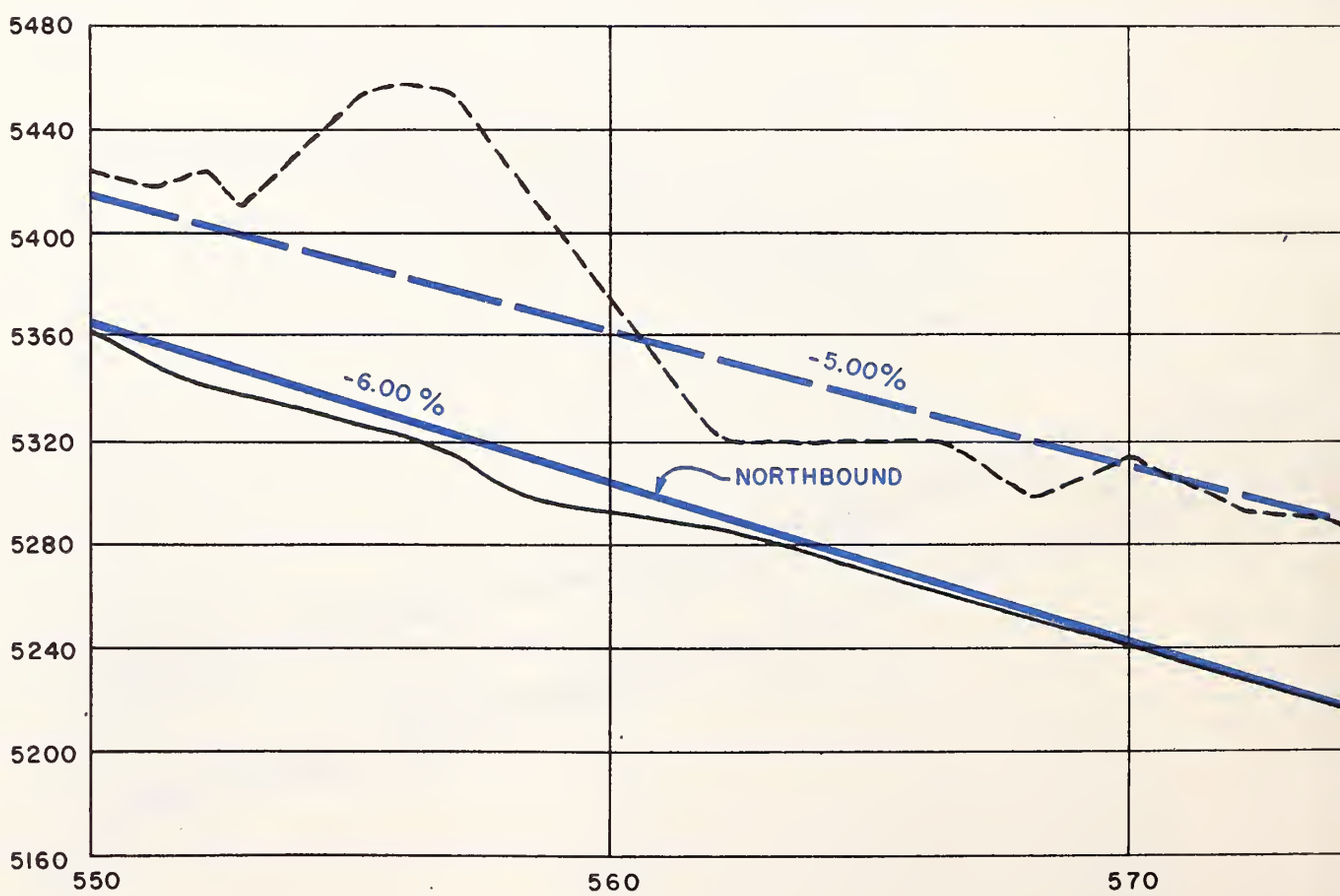
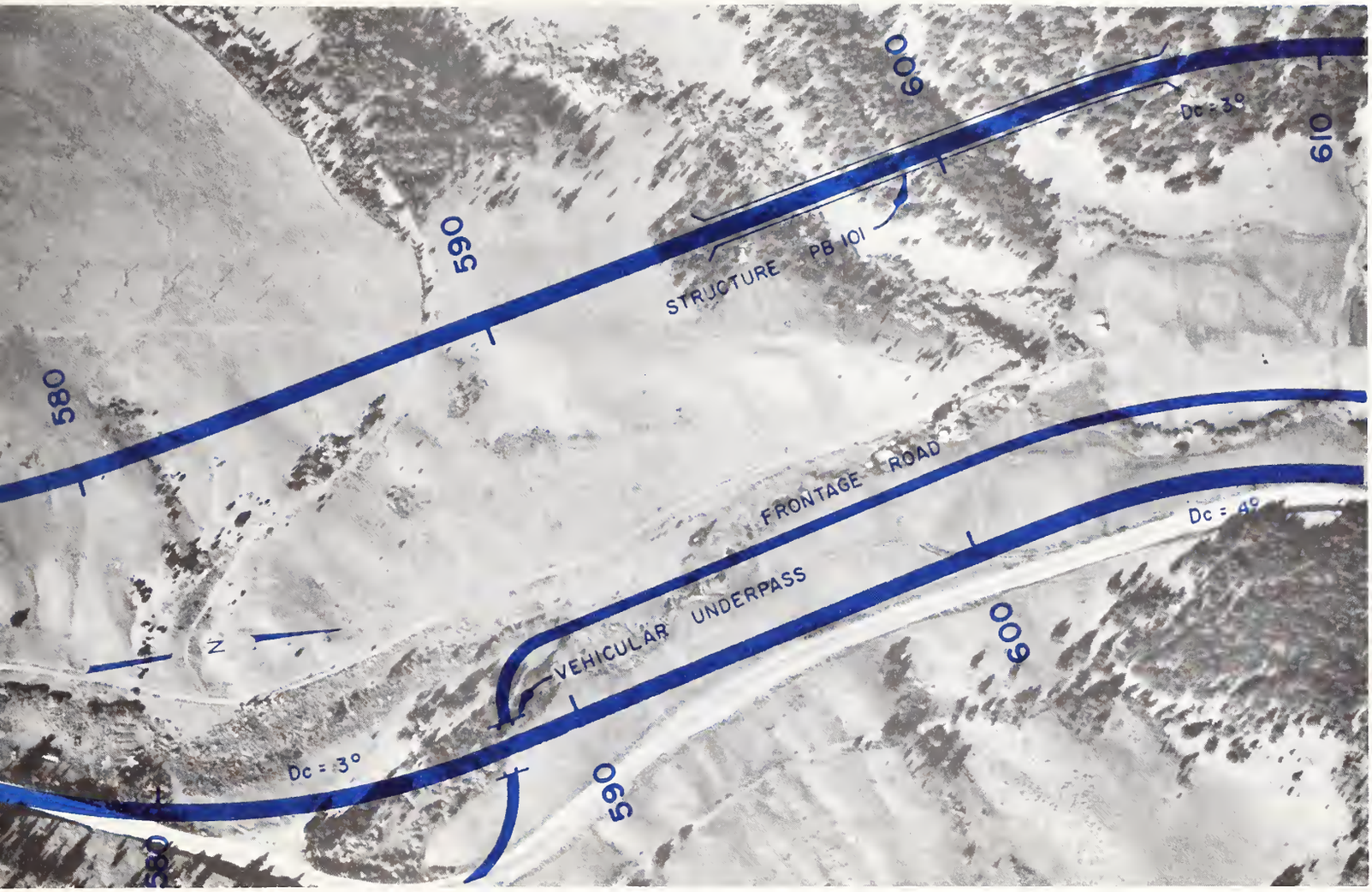


FIGURE 47



ALTERNATE 5

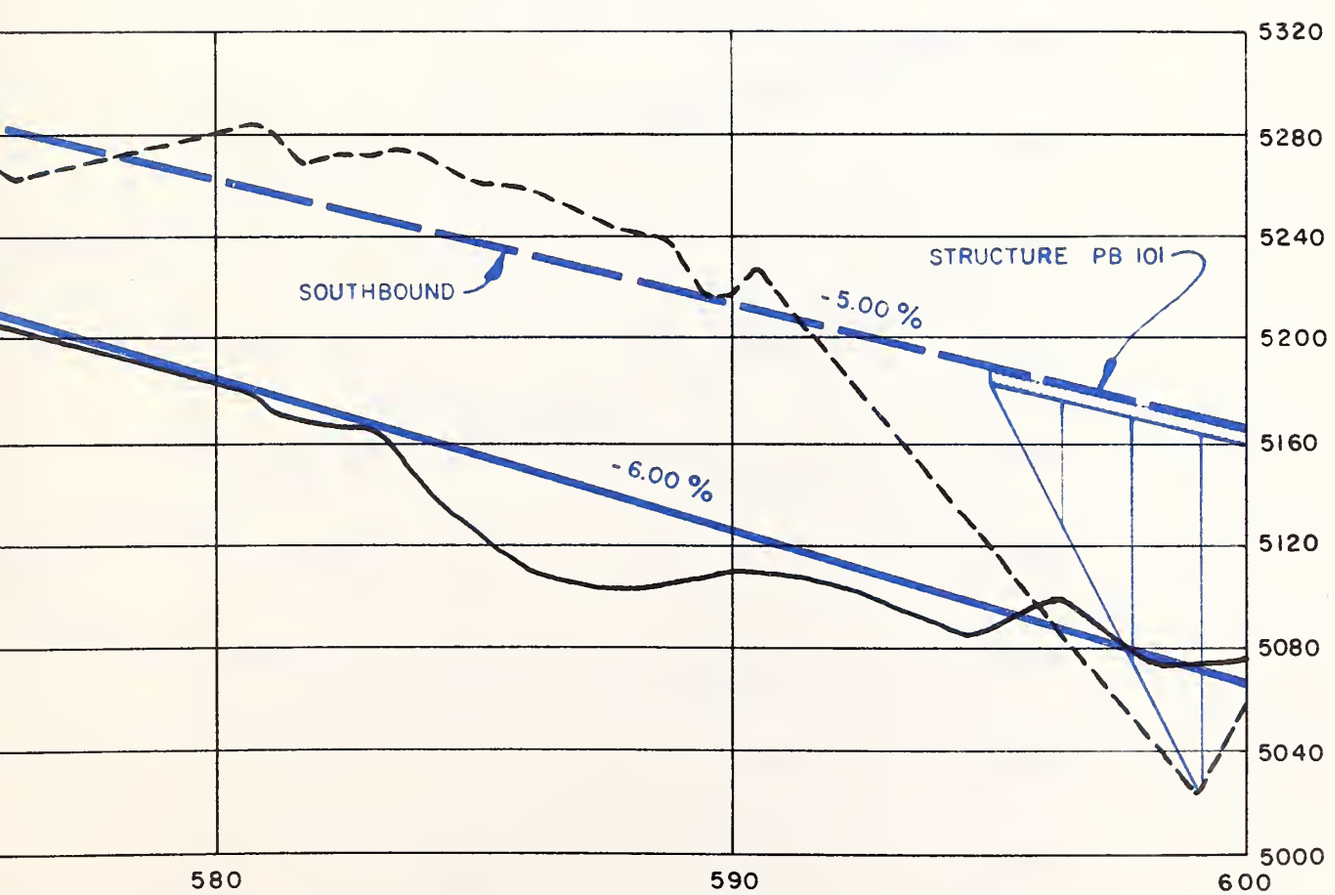


FIGURE 48

ALTERNATE 5

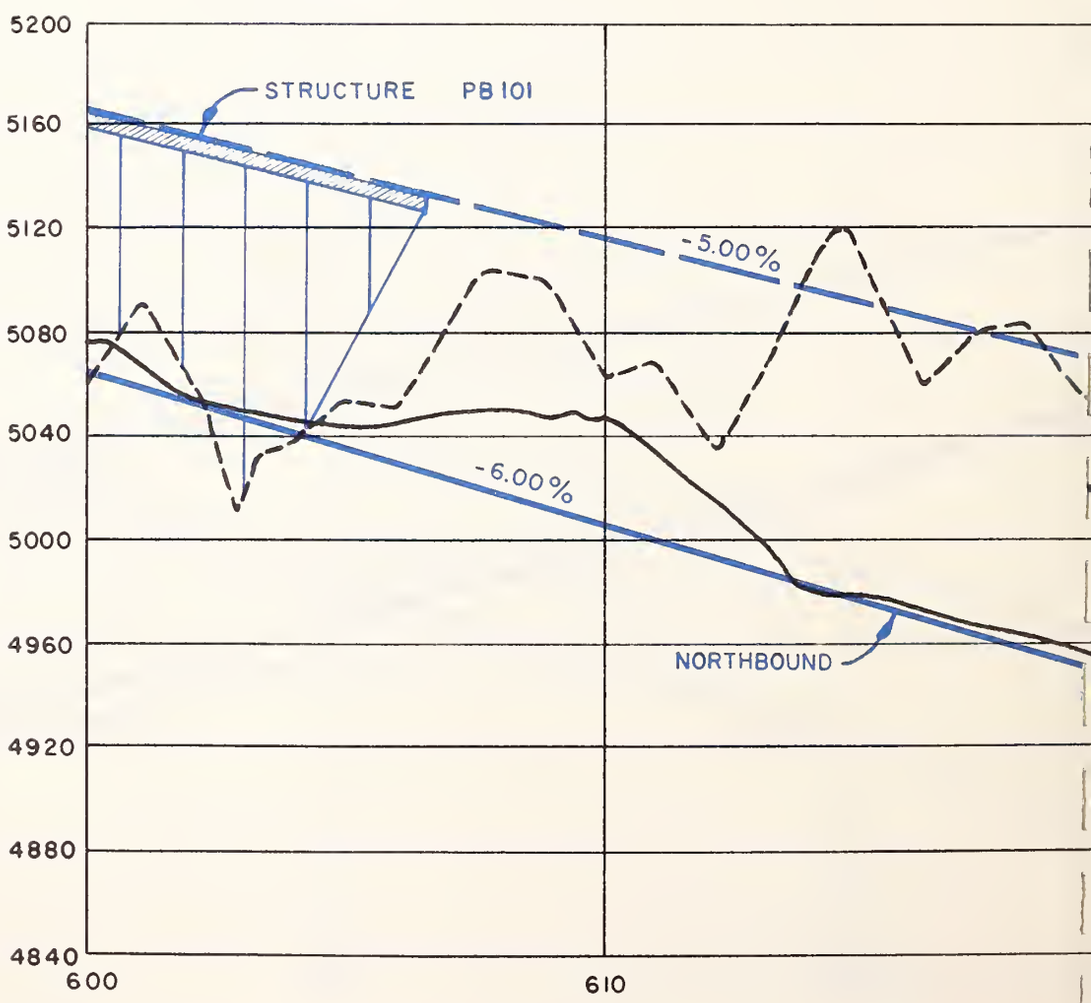
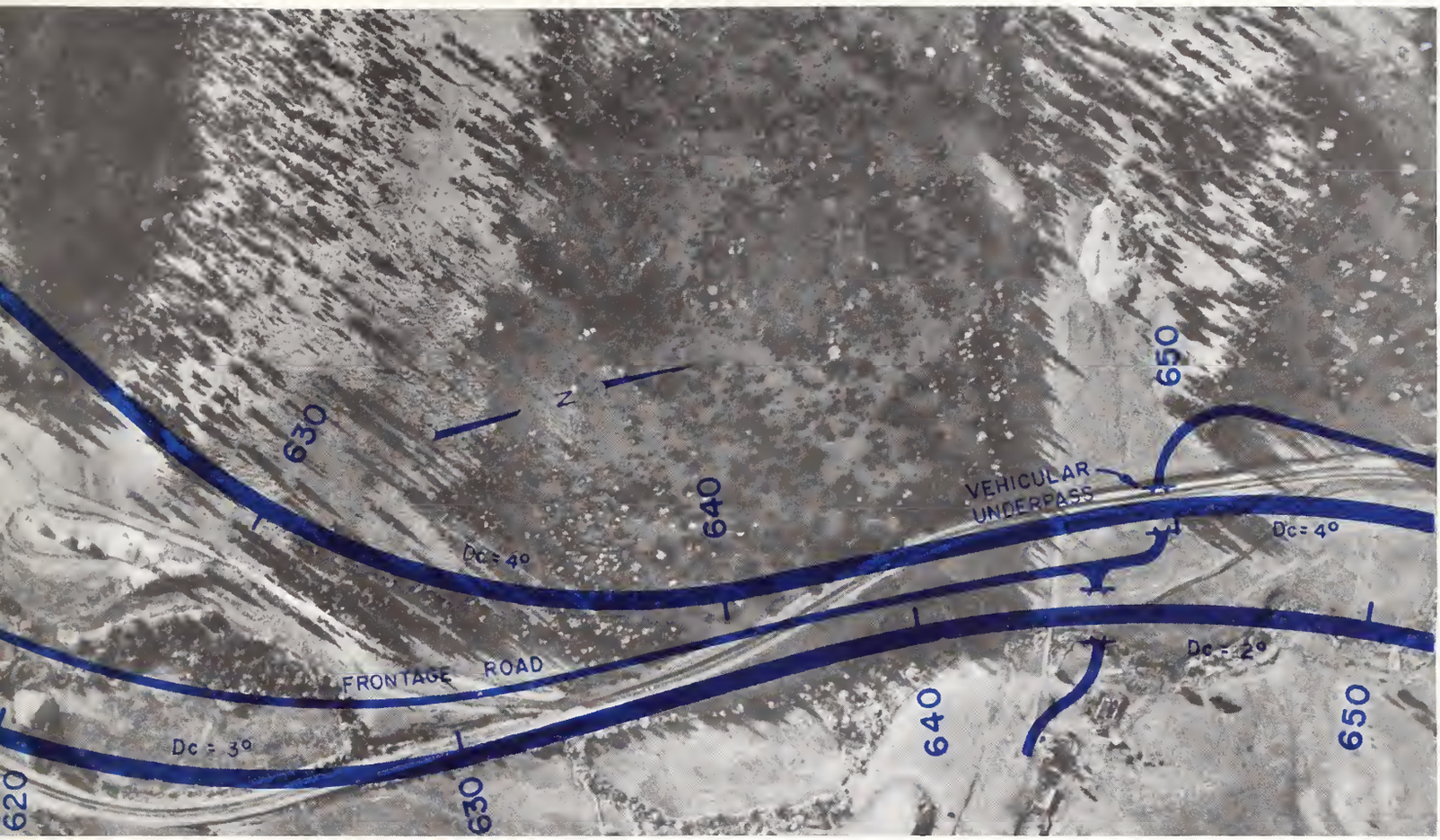


FIGURE 49



ALTERNATE 5

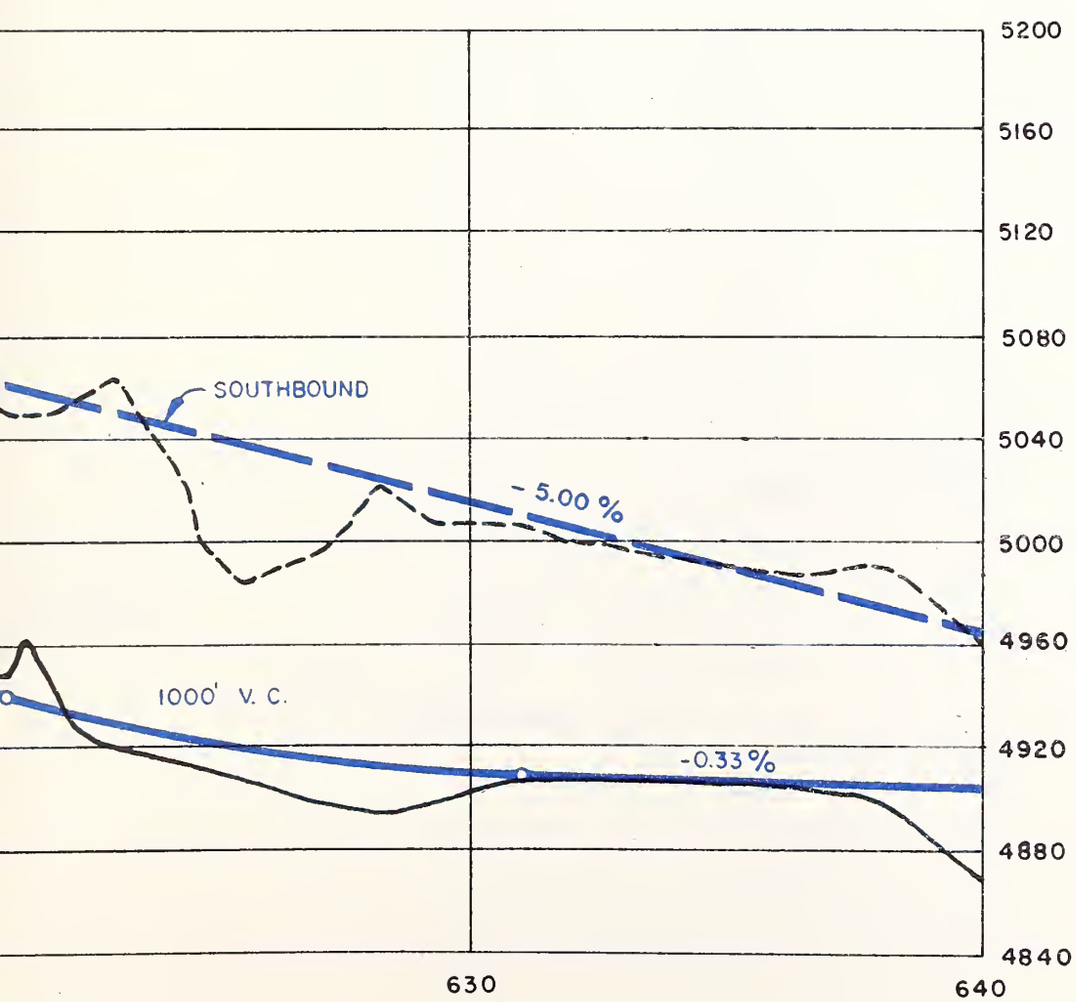
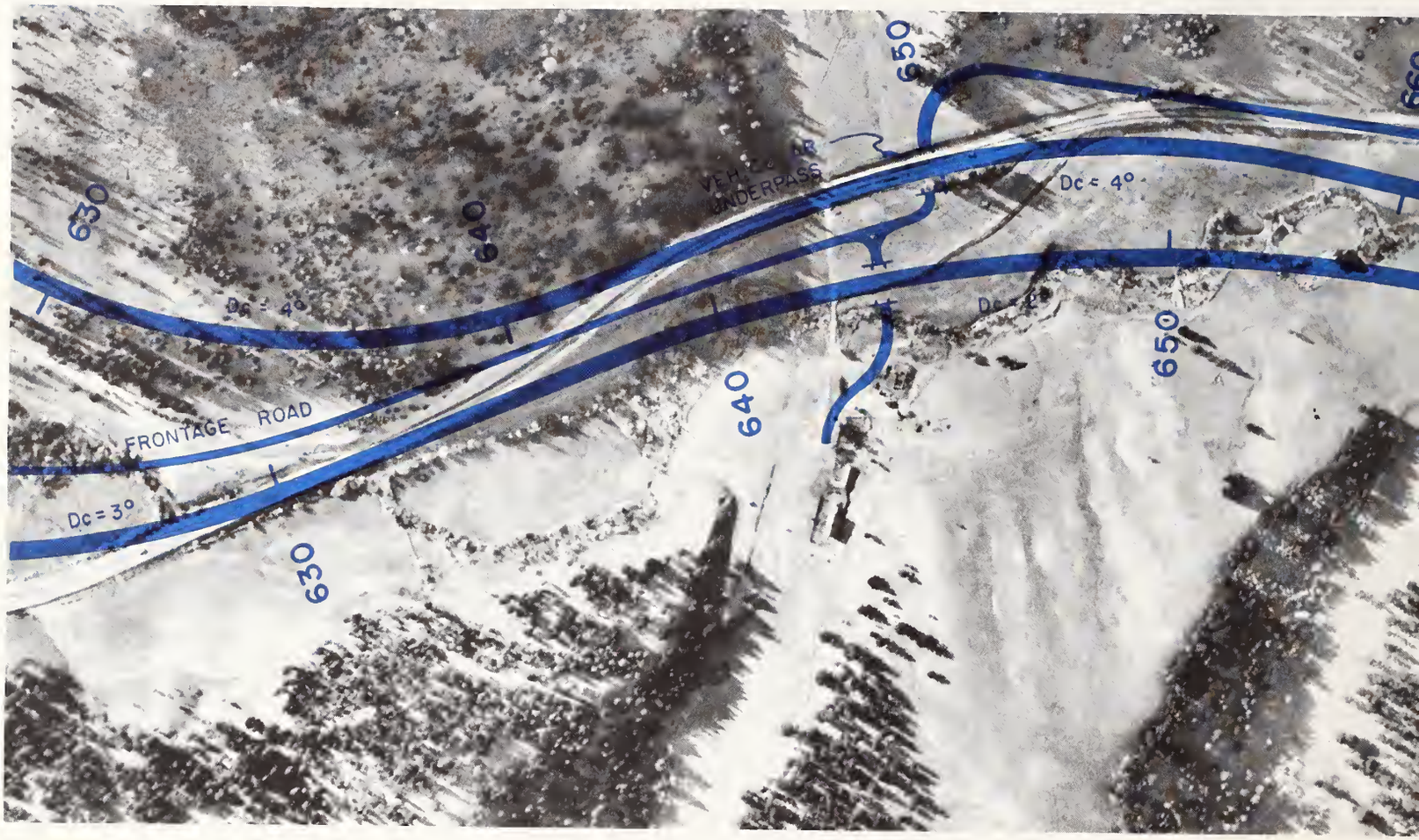


FIGURE 50



ALTERNATE 5

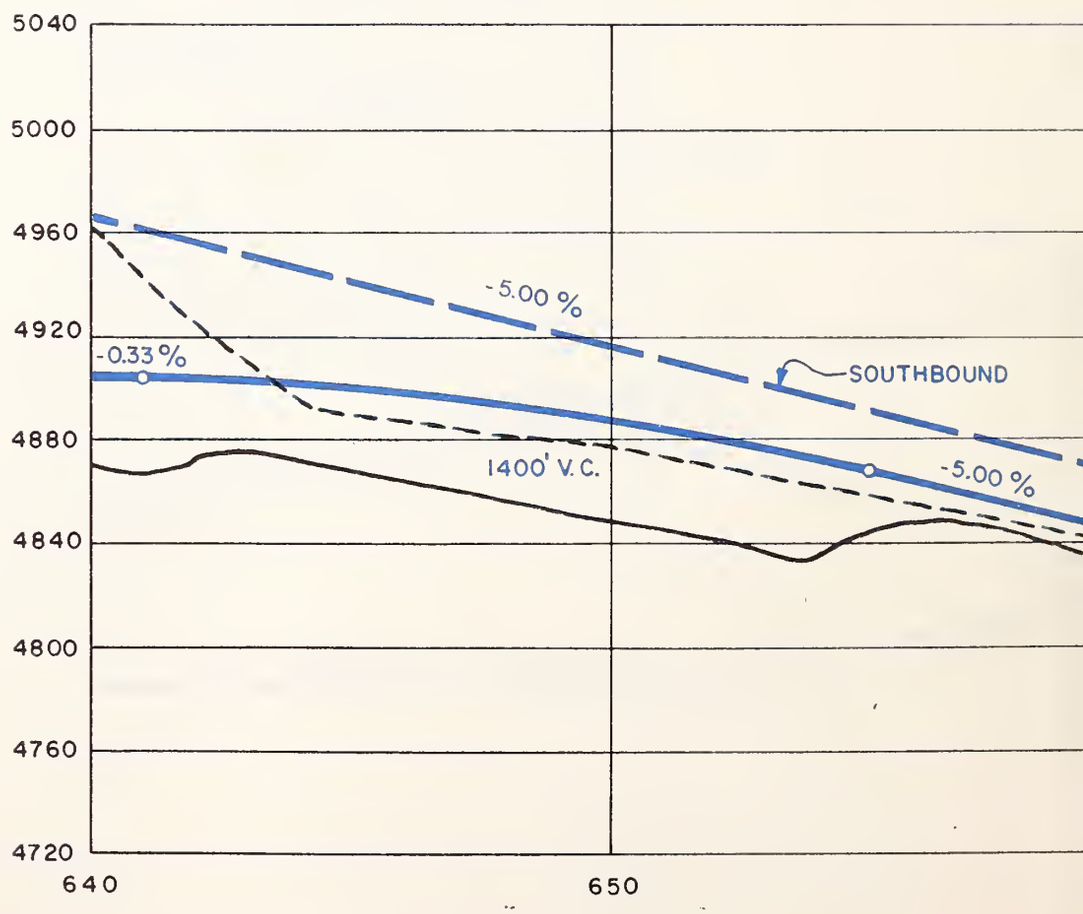
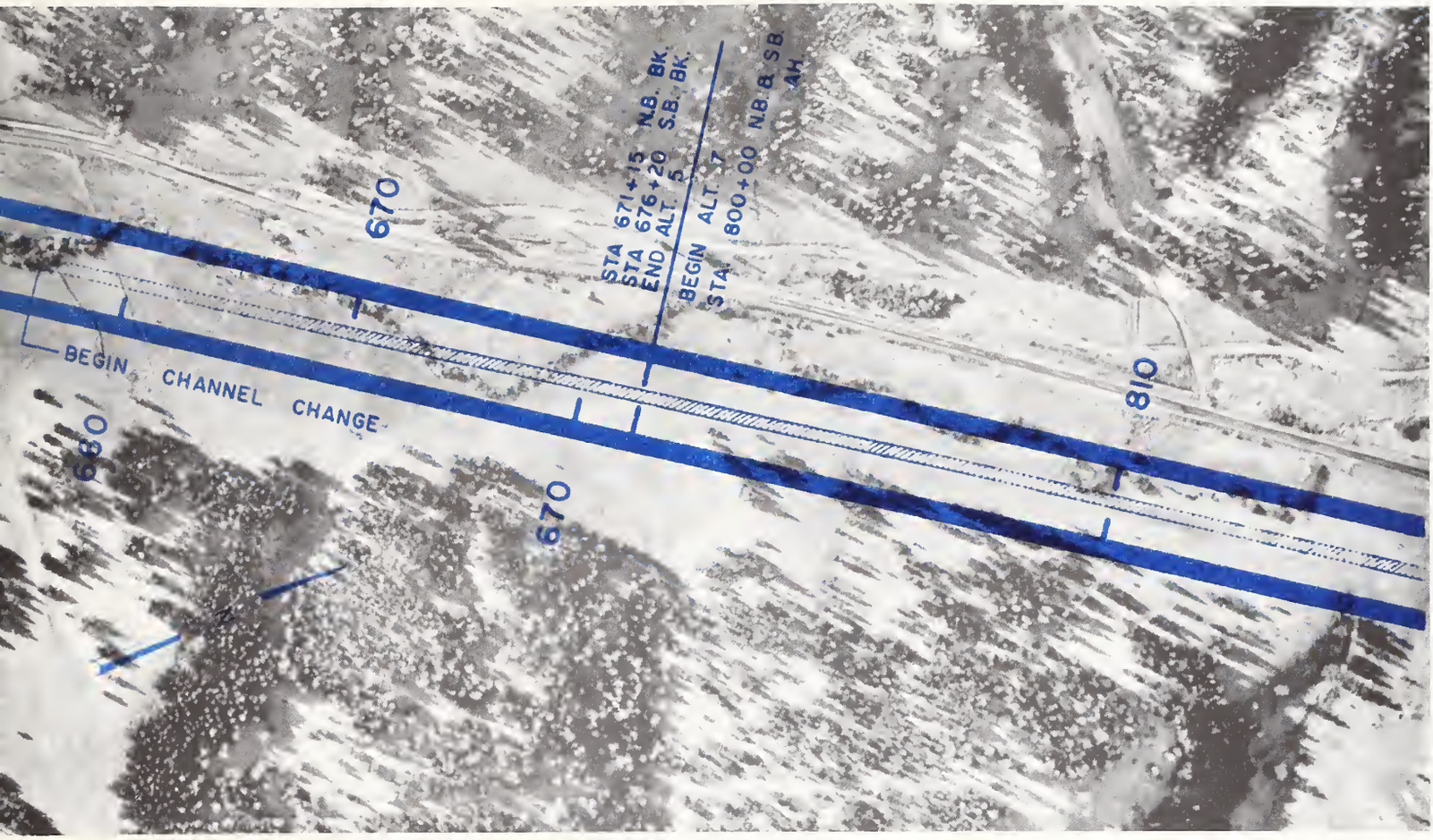


FIGURE 51



ALTERNATE 5

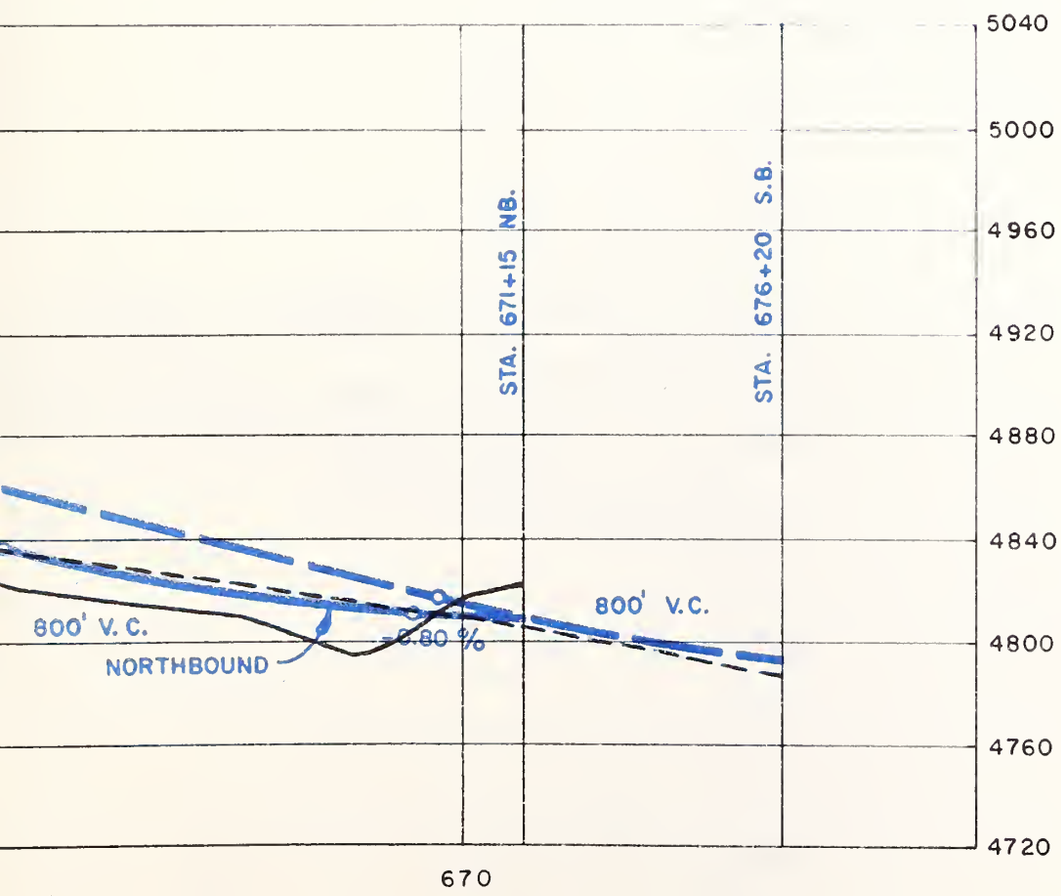
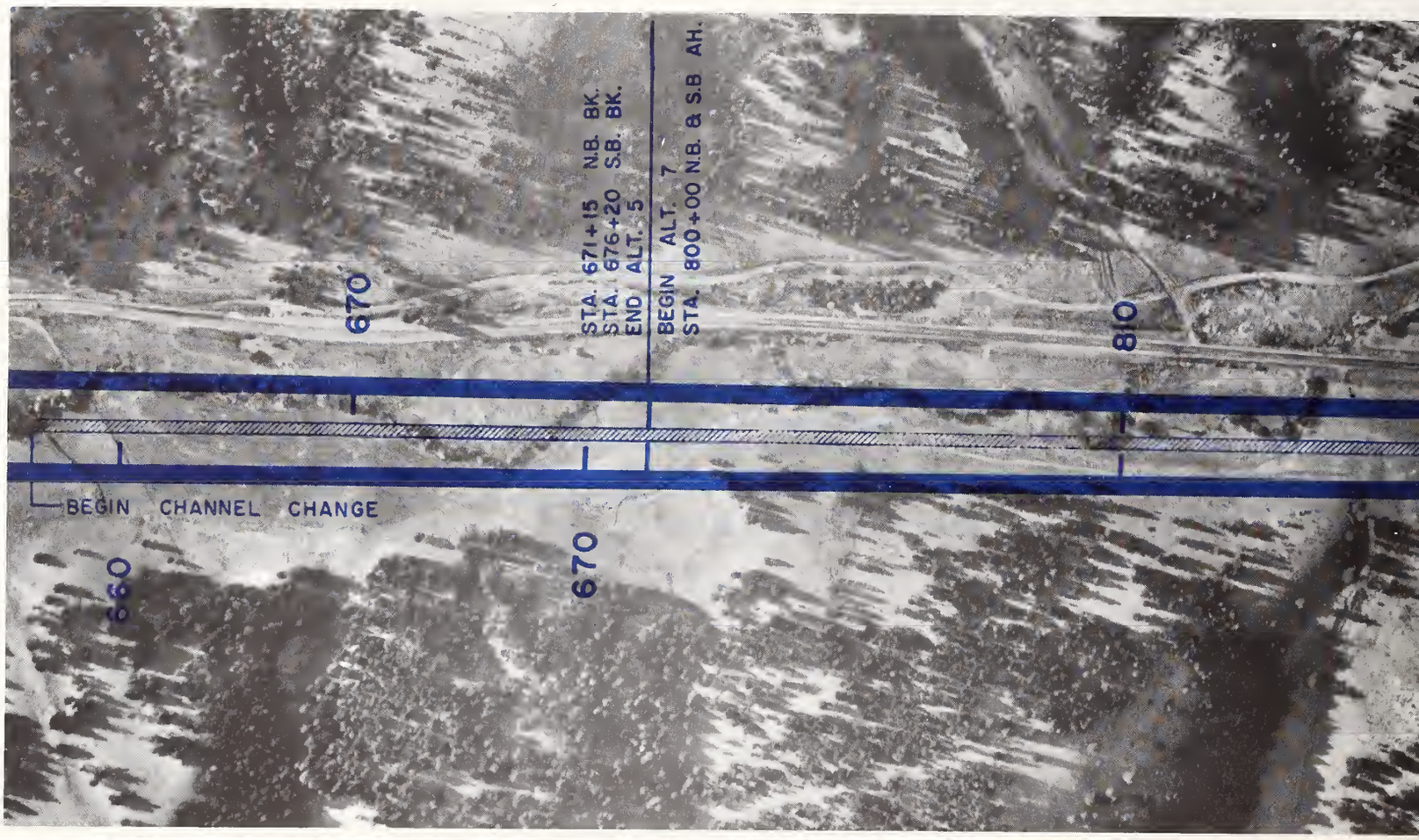


FIGURE 52



ALTERNATE 7

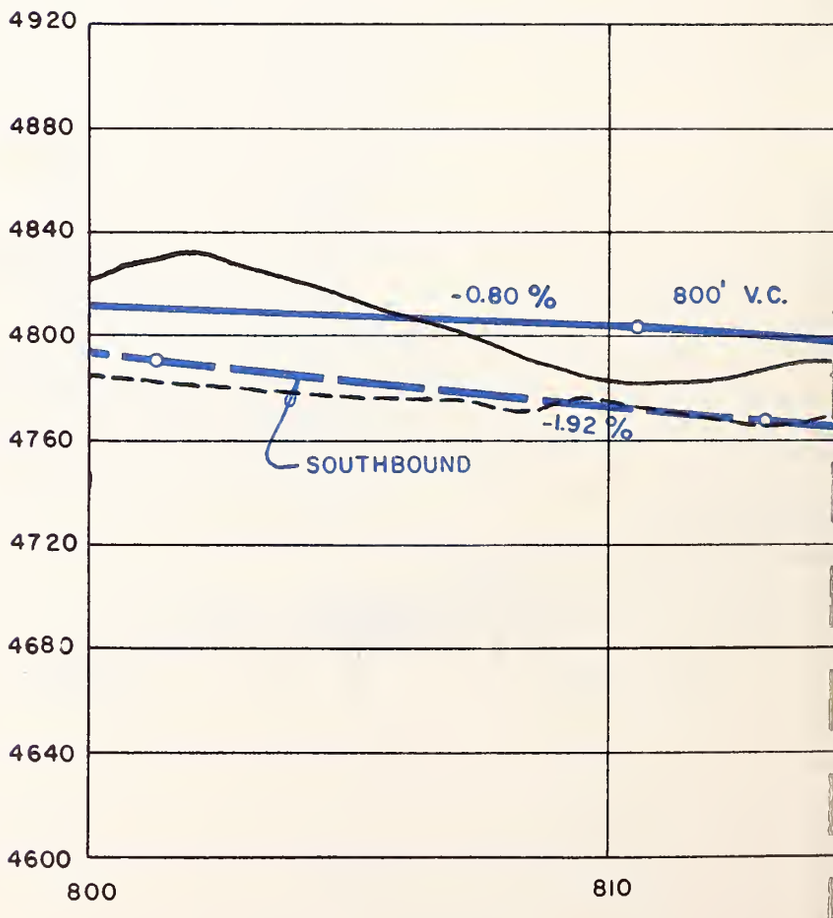
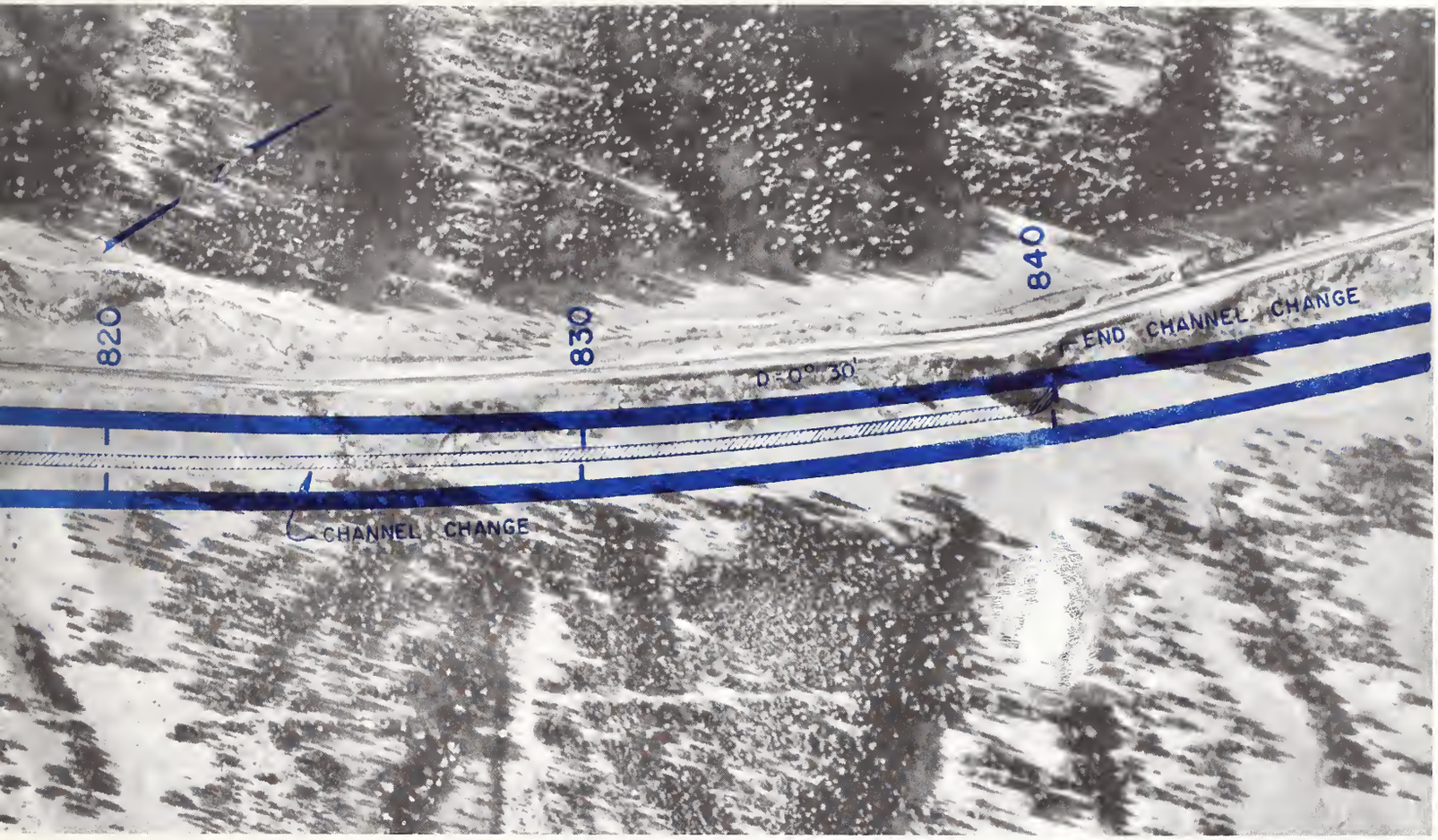


FIGURE 53



ALTERNATE 7

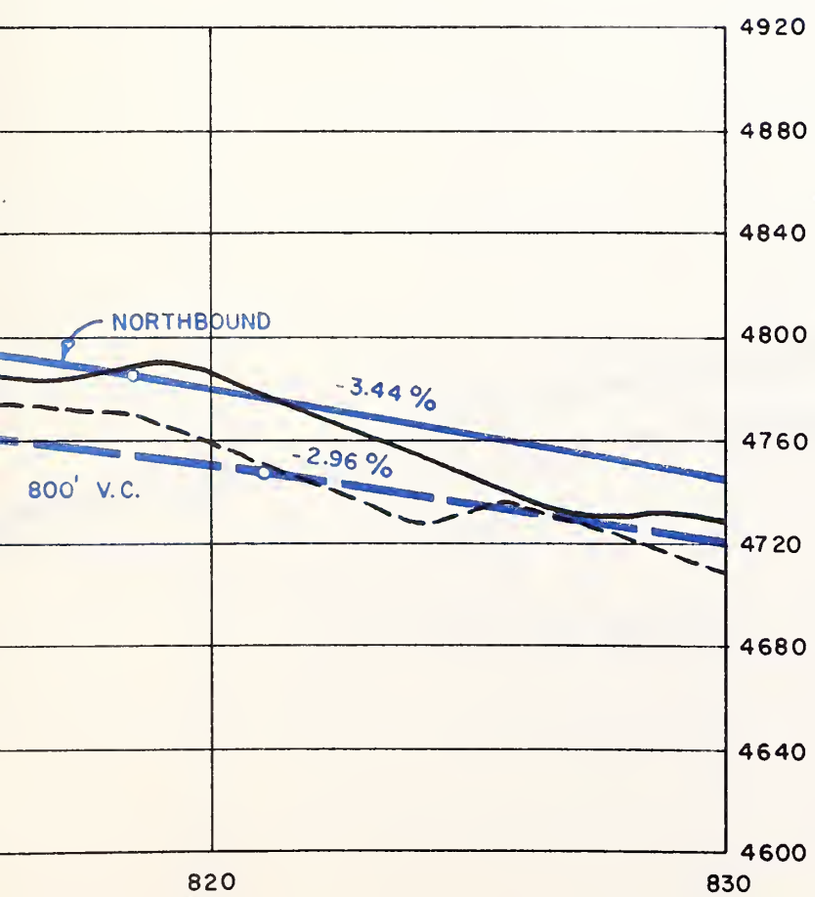
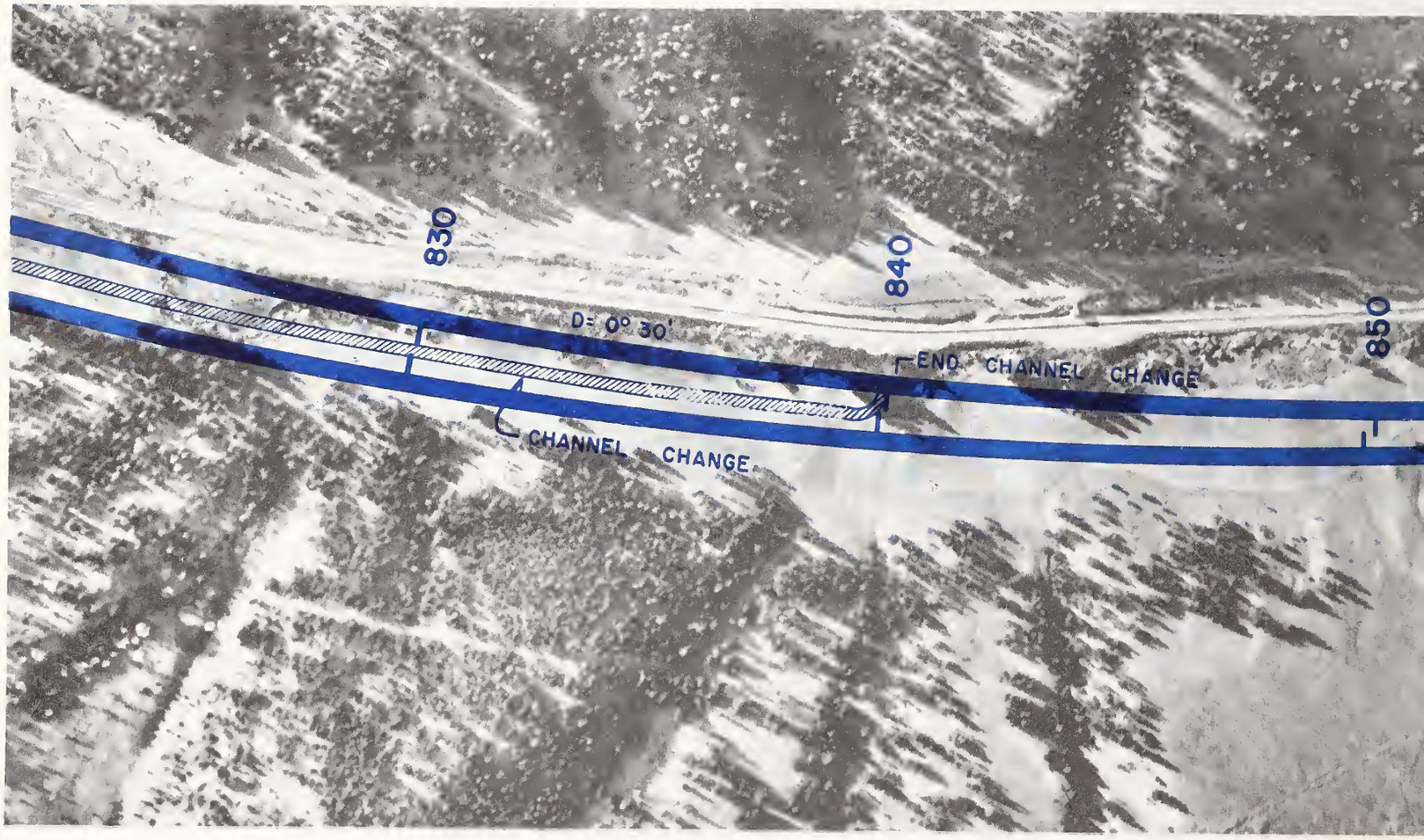
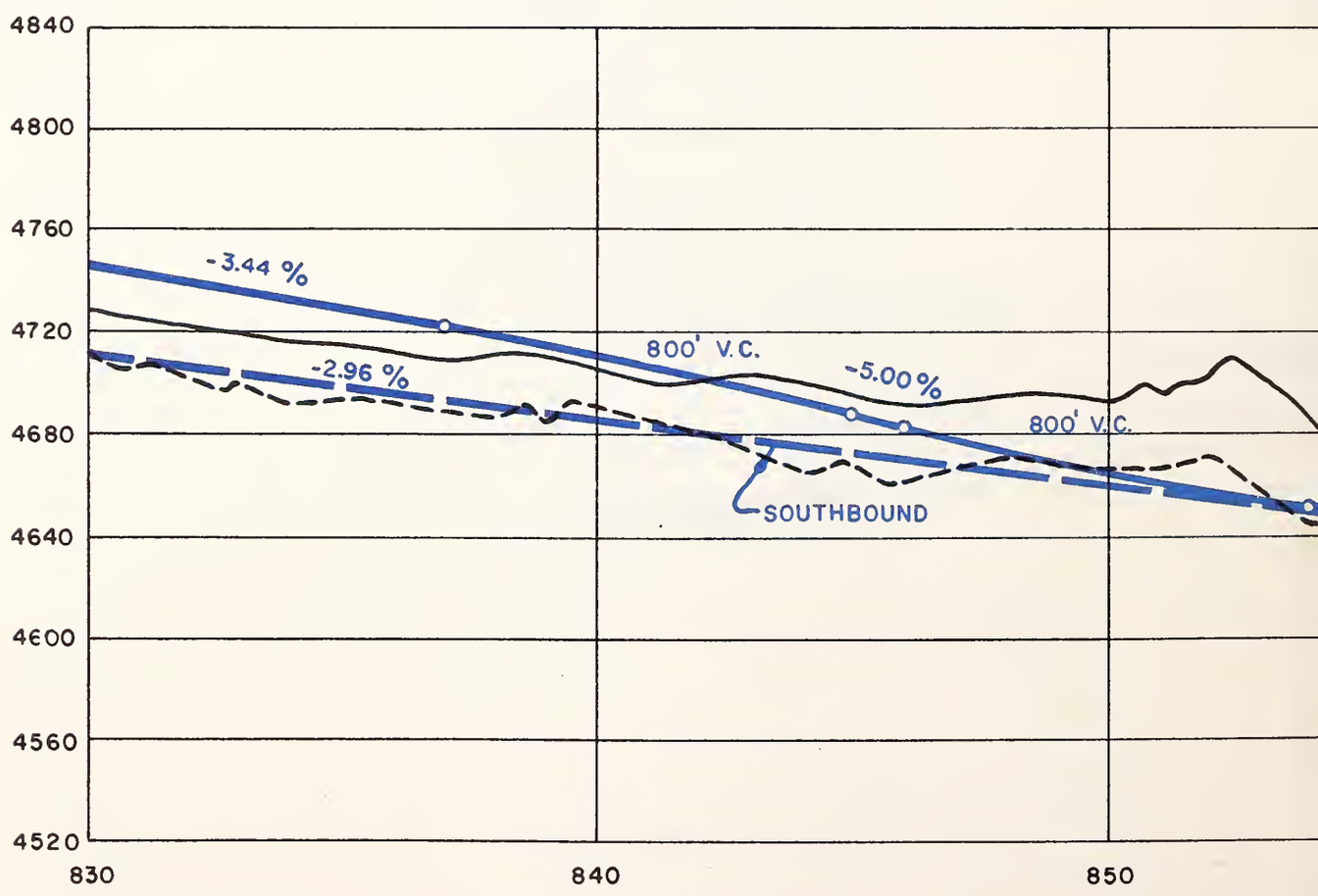
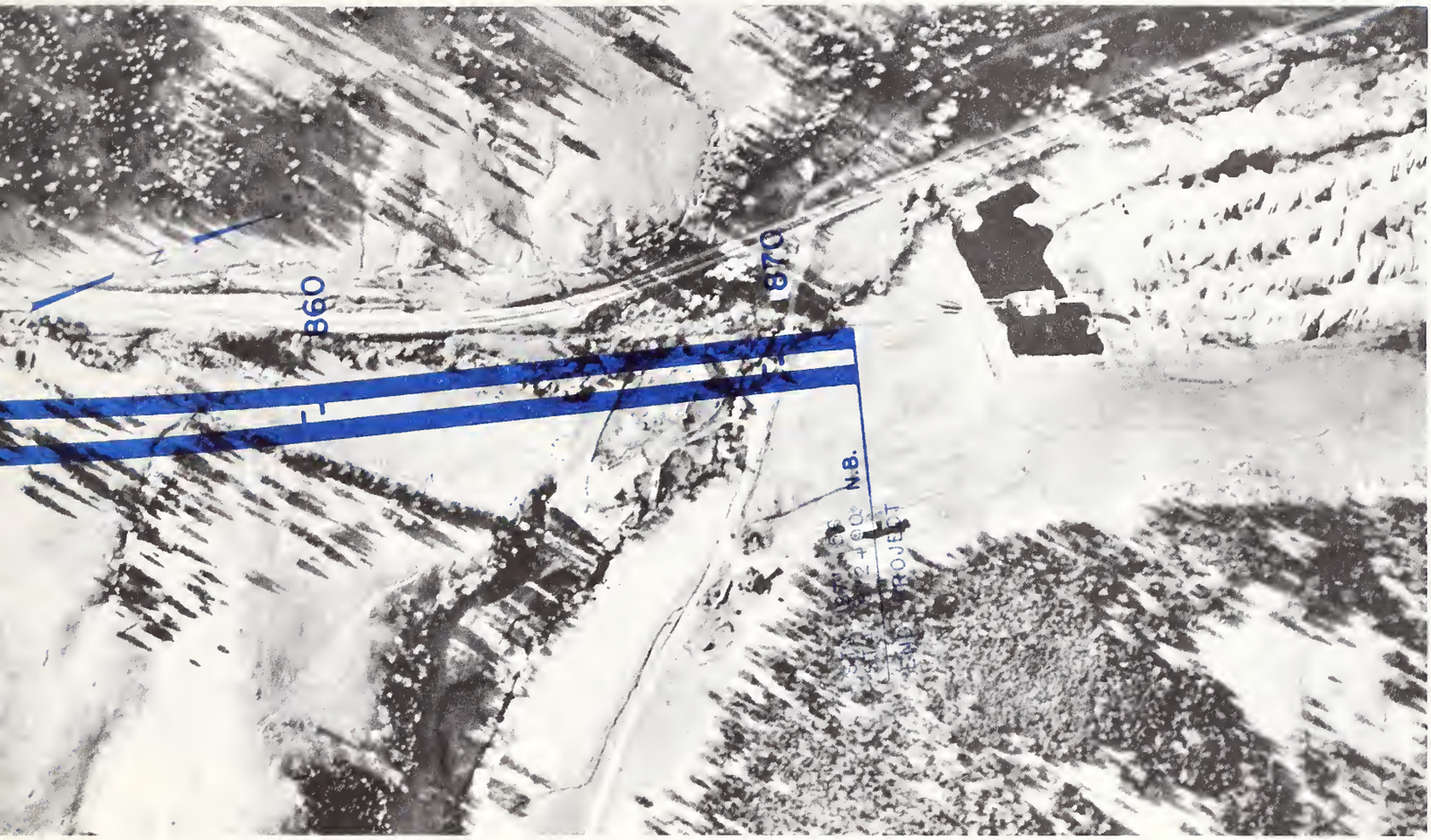


FIGURE 54



ALTERNATE 7




860
870
N.B.
PROJECT

ALTERNATE 7

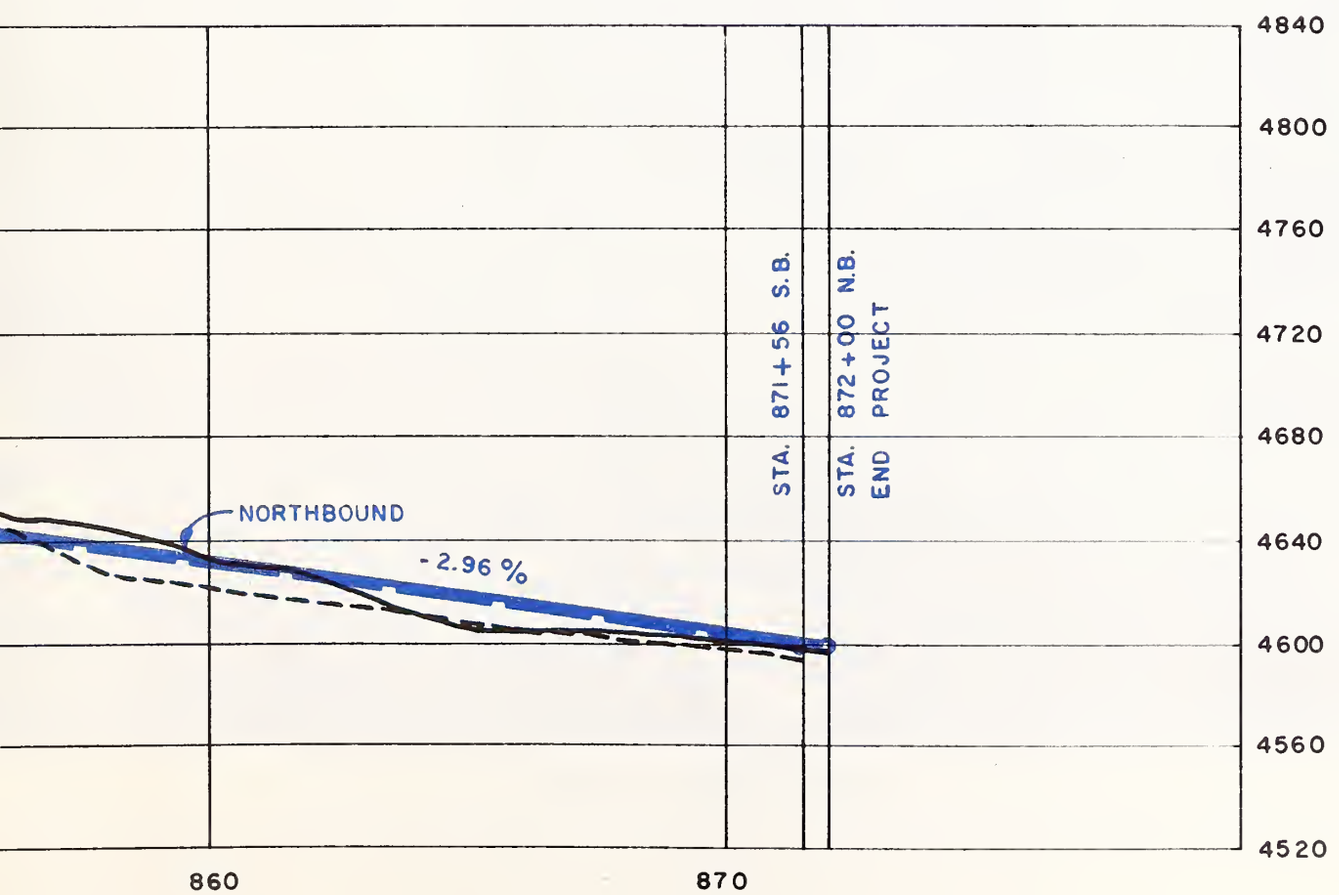
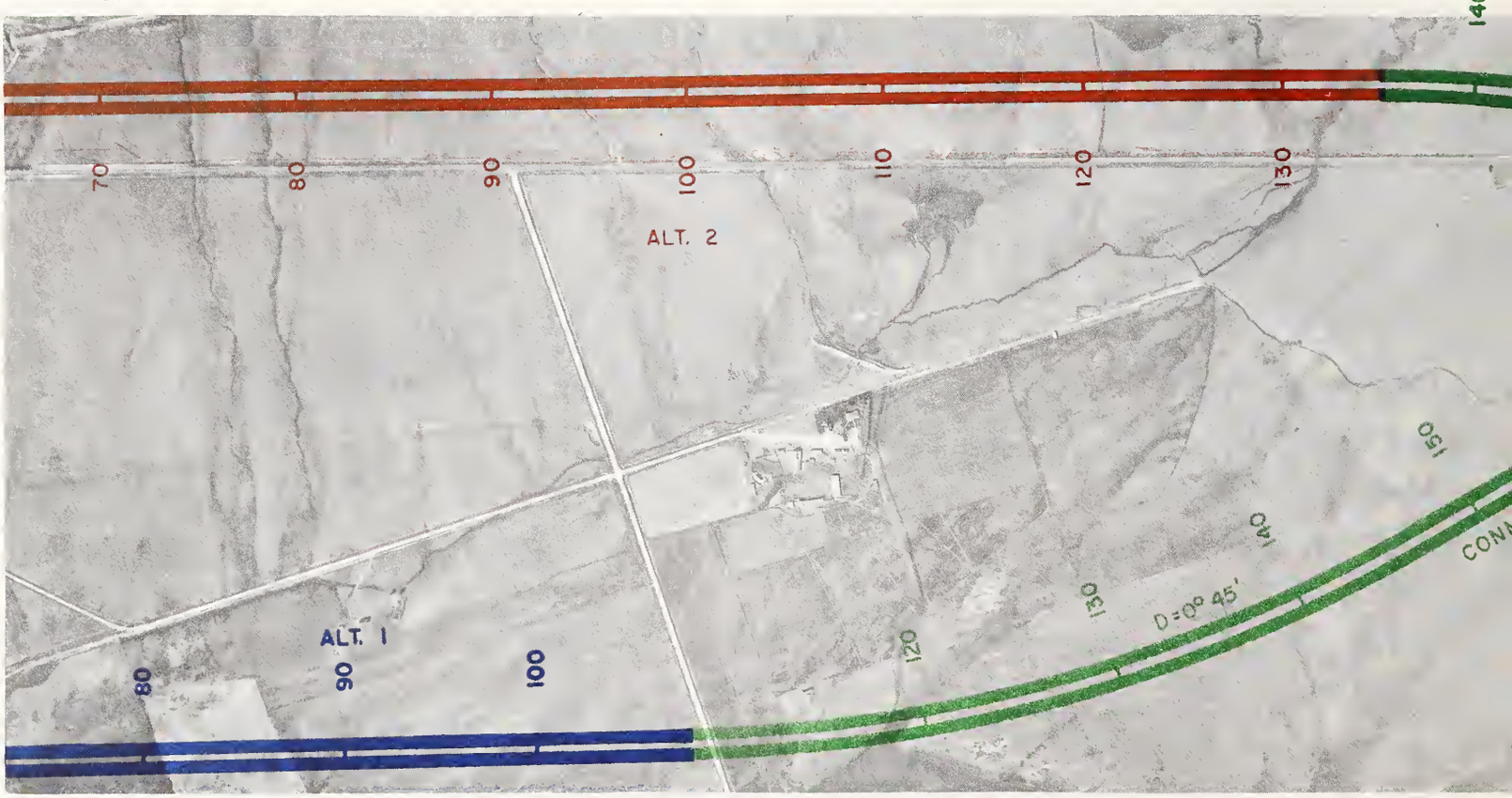
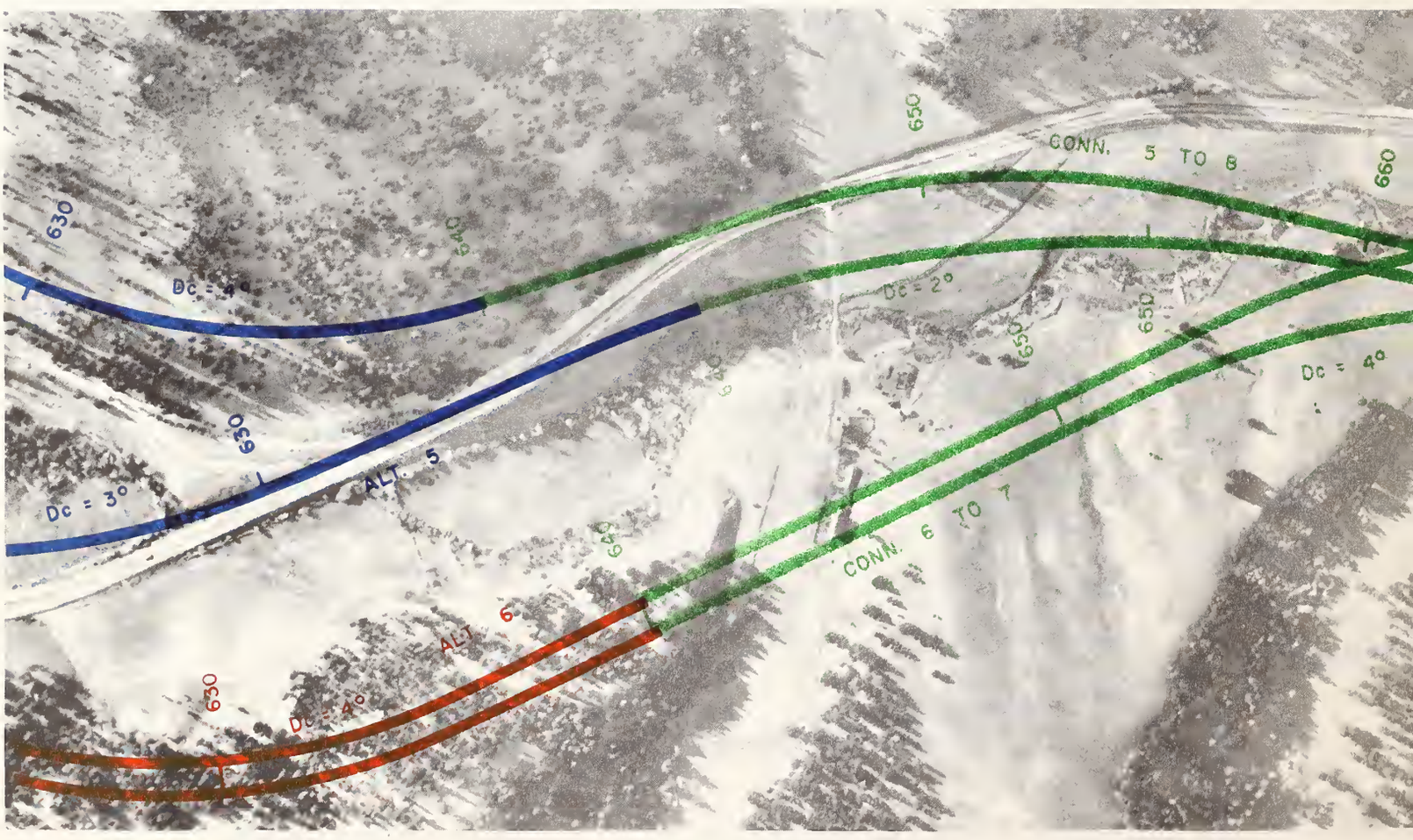

4840
4800
4760
4720
4680
4640
4600
4560
4520
STA. 871+56 S.B.
STA. 872+00 N.B.
END PROJECT
NORTHBOUND
-2.96 %
860
870

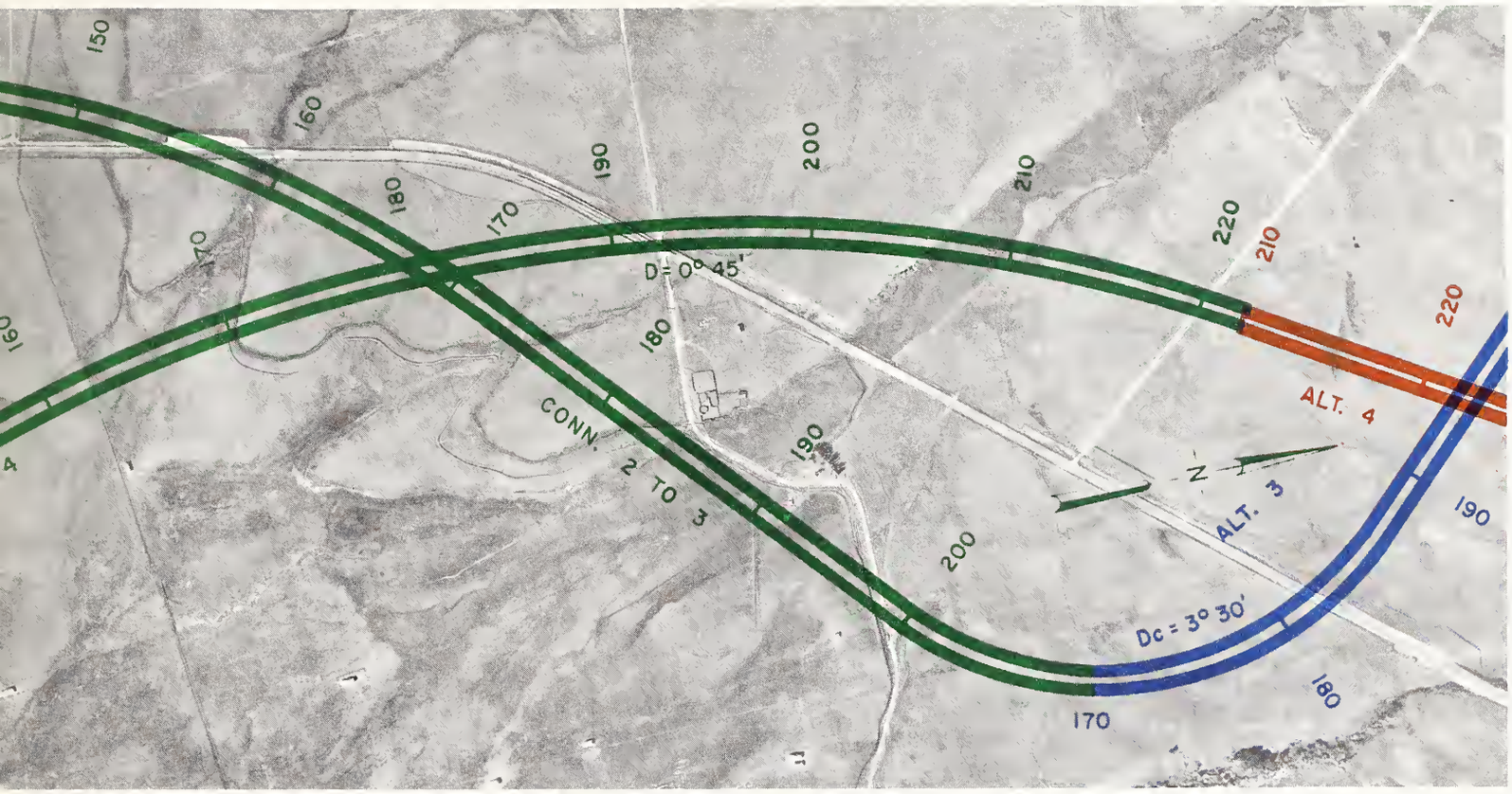
FIGURE 56



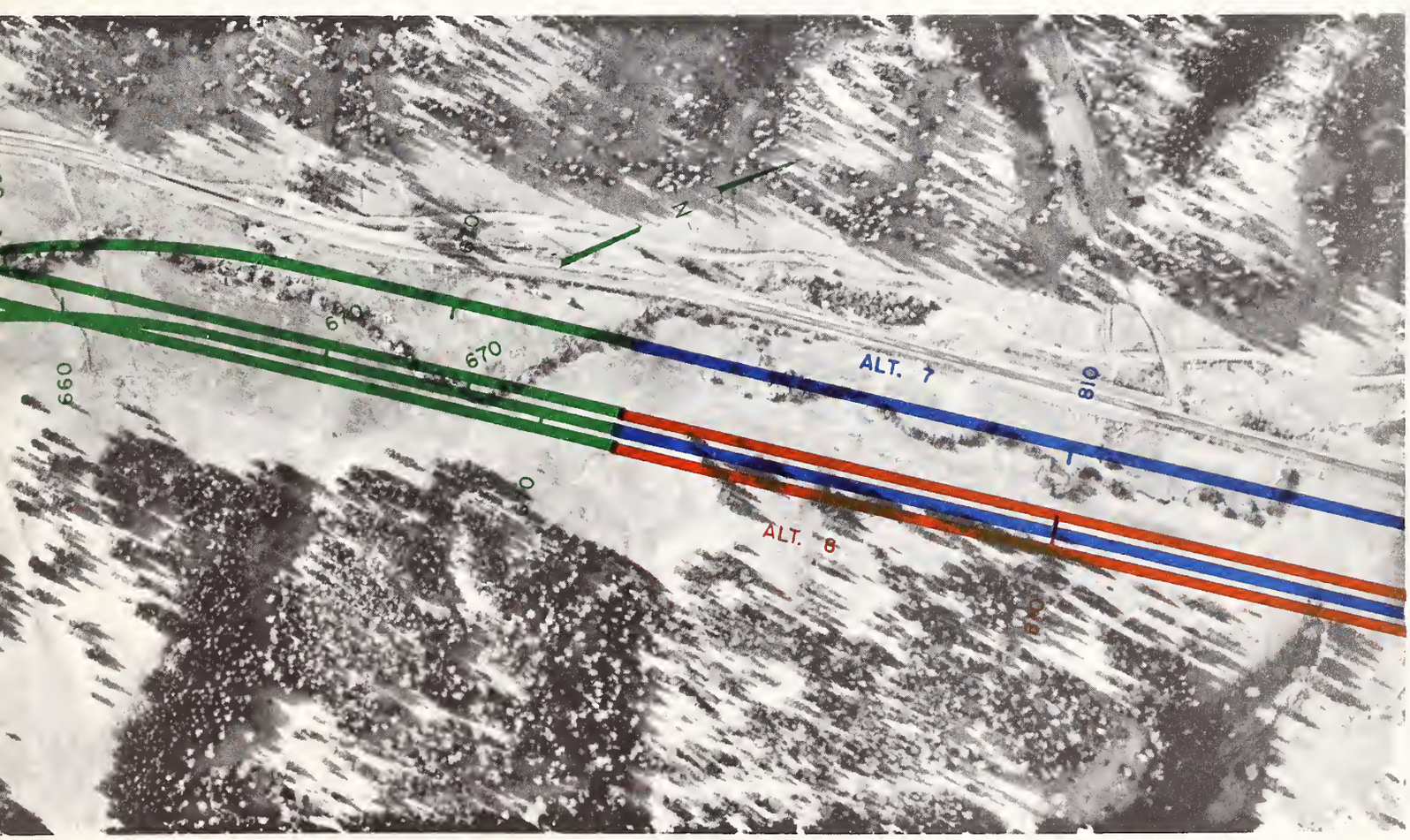
CONNECTIONS



CONNECTIONS



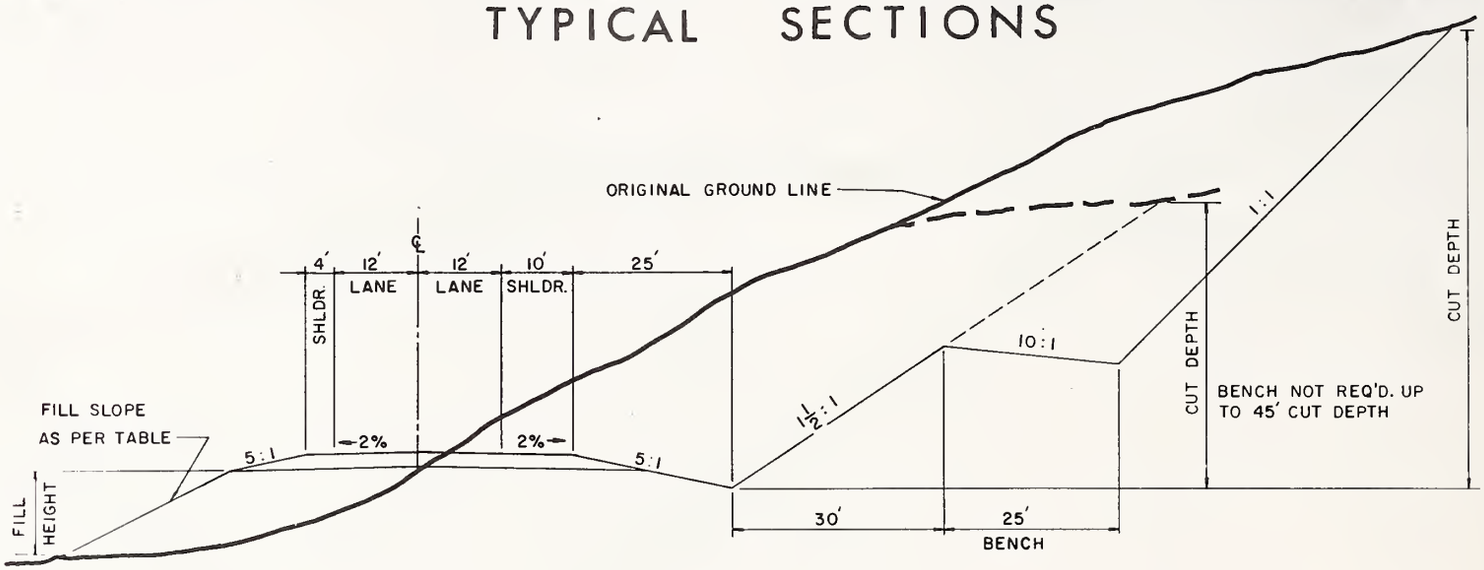
SCALE: 1" = 1000'



SCALE: 1" = 400'

FIGURE 58

TYPICAL SECTIONS



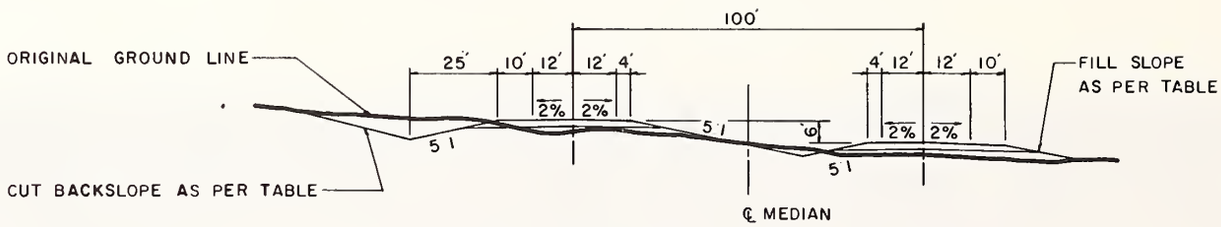
TYPICAL 4-LANE WIDE MEDIAN WITH INDEPENDENT GRADES & ALINEMENT

(2 LANES ONLY SHOWN)

USED FOR ALTERNATE 3, ALTERNATE 4 (STA. 130 TO STA. 223), ALTERNATE 5, ALTERNATE 6 (STA. 500 TO STA. 550), & ALTERNATE 7

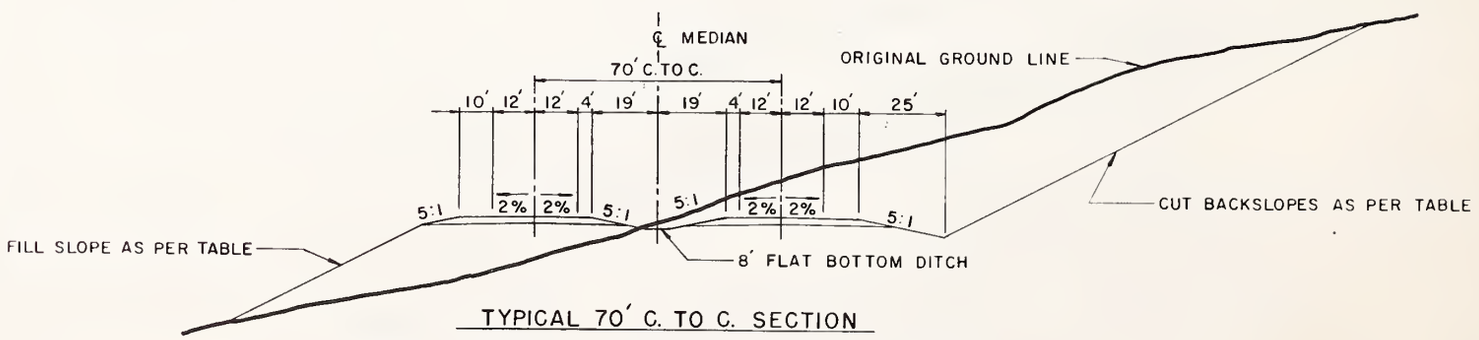
BACKSLOPES

CUT OR FILL DEPTH	0'-5'	5'-10'	10'-15'	15'-20'	OVER 20'
CUT SLOPE	5:1	4:1	3:1	2:1	SEE DETAIL
FILL SLOPE	5:1	3:1	2½:1	2:1	2:1



TYPICAL 100' C. TO C. SECTION

(TANGENT SECTION NO. 4 & CURVE SECTION NO. 4 OF MONTANA HWY. DEPT. STANDARDS, NORTHBOUND SECTION 6' BELOW PROFILE GRADE LINE) USED FOR ALTERNATE 2 STA. 0+00 TO STA. 190+00.



TYPICAL 70' C. TO C. SECTION

(TANGENT SECTION NO. 3 & CURVE SECTION NO. 3 OF MONTANA HWY. DEPT. STANDARDS) USED FOR ALTERNATE 4 (STA 223 TO STA. 243), ALTERNATE 6 (STA. 570 TO STA. 672), & ALTERNATE 8.

TYPICAL 100' C. TO C. SECTION (NOT ILLUSTRATED)

(TANGENT SECTION NO. 4 & CURVE SECTION NO. 4 OF MONTANA HWY. DEPT. STD'S.) USED FOR ALTERNATE 1, STA. 0+00 TO STA. 210+00.

FRONTAGE ROAD NOTE

FRONTAGE ROAD TYPICAL SECTION IS ACCORDING TO MONTANA HWY DEPT STD NO 33

COST SUMMARY OF ALIGNMENTS

Alternate Combination	Total Length In Miles	Total Initial Cost	Total Annual Cost
1 3 5 7	11.23	$7,047,604	$1,923,376
1 3 5 8	11.22	$7,019,748	$1,919,494
1 3 6 7	11.26	$6,680,273	$1,900,559
1 3 6 8	11.26	$6,662,508	$1,899,446
1 4 5 7	11.04	$7,184,445	$1,907,213
1 4 5 8	11.03	$7,156,589	$1,903,331
1 4 6 7	11.07	$6,817,114	$1,884,396
1 4 6 8	11.07	$6,799,349	$1,883,283
2 3 5 7	11.23	$7,016,767	$1,924,332
2 3 5 8	11.22	$6,988,911	$1,920,450
2 3 6 7	11.26	$6,649,436	$1,901,515
2 3 6 8	11.26	$6,631,671	$1,900,402
2 4 5 7	10.80	$7,117,037	$1,874,737
2 4 5 8	10.79	$7,089,181	$1,870,855
2 4 6 7	10.83	$6,749,706	$1,851,920
2 4 6 8	10.83	$6,731,941	$1,850,807

NOTES:

1. The total Initial Cost is the initial project Construction costs including Right-of-Way costs.

2. The Total Annual Cost is the sum of the annual costs for Construction, Maintenance, and Vehicle Operation.

GEOMETRIC SUMMARY

Alternate	Length Miles	Average Grade %	Maximum * Grade %	Percent Of Curvature	Average Degree Of Curvature	Maximum Degree Of Curvature	Total Horizontal Deflection
1	2.08	0.57	1.28	12.93	0° 30'	0° 30'	7°
Conn. 1-3	1.89	1.06	2.40	-	-	-	-
Conn. 1-4	2.13	1.23	5.00	91.64	0° 45'	0° 45'	85°
2	2.08	1.70	3.44	14.22	1° 54'	2° 00'	39°
Conn. 2-3	1.89	1.23	2.40	71.33	1° 39'	3° 30'	75°
Conn. 2-4	1.89	1.17	5.00	43.06	0° 30'	0° 30'	16°
3	2.61	5.00	6.00	60.72	2° 40'	4° 00'	227°
4	2.18	5.26	6.00	66.57	1° 50'	4° 00'	157°
5	2.65	5.21	6.00	70.22	2° 29'	4° 00'	231°
Conn. 5-7	0.64	3.87	5.00	44.86	2° 20'	4° 00'	37°
Conn. 5-8	0.63	3.67	5.00	45.57	2° 20'	4° 00'	37°
6	2.69	4.87	6.00	72.10	2° 07'	4° 00'	224°
Conn. 6-7	0.63	4.95	5.00	41.48	2° 51'	4° 00'	39°
Conn. 6-8	0.63	5.00	5.00	41.63	2° 50'	4° 00'	39°
7	1.36	2.81	5.00	52.94	0° 30'	0° 30'	19°
8	1.36	2.90	3.44	52.80	0° 30'	0° 30'	19°

* Maximum Ascending Grade is 5%.

CONSTRUCTION COST SUMMARY AND COMPARISON OF ALTERNATES STUDIED

Alternate	Length Miles	Clearing & Grubbing	Maintenance Of Traffic	Earthwork	Guard Rail	Surfacing	Small Drainage Structures	Major Structures	Fencing & Signing	Right Of Way	Relocate Utilities	Total Cost
1	2.08			$ 126,556		$283,690	$ 36,600		$10,670	$20,864		$ 478,380
Conn. 1-3	1.89			$ 104,454	$ 2,500	$261,900	$ 40,850	$ 95,000	$ 9,700	$28,981		$ 543,385
Conn. 1-4	2.13			$ 112,641	$ 4,750	$300,622	$ 44,700	$ 95,000	$10,893	$22,680		$ 591,286
2	2.08			$ 182,818	$ 7,750	$237,050	$ 42,616		$10,670	$ 7,229	$23,800	$ 511,933
Conn. 2-3	1.89			$ 89,816	$ 2,250	$218,500	$ 50,700	$100,000	$ 9,700	$ 7,229	$ 800	$ 478,995
Conn. 2-4	1.89			$ 94,816	$ 2,250	$228,500	$ 49,200	$100,000	$ 9,700	$ 5,059	$ 800	$ 490,325
3	2.61	$15,750	$65,104	$1,424,192	$42,125	$300,910	$ 39,150		$13,373	$ 4,967	$ 4,400	$1,909,971
4	2.18	$ 6,000	$34,669	$1,599,500	$33,400	$252,056	$ 58,200		$11,174	$ 3,912		$1,998,911
5	2.65	$23,000	$41,800	$1,762,718	$33,000	$286,395	$ 79,130	$650,000	$12,513	$10,007	$85,600	$2,984,163
Conn. 5-7	0.64	$ 5,000	$11,302	$ 306,000	$14,250	$ 75,180	$ 66,920		$ 3,267	$ 6,532	$33,700	$ 522,151
Conn. 5-8	0.63	$ 5,000	$11,302	$ 243,853	$13,500	$ 75,134	$ 83,770		$ 3,238	$ 4,932	$21,400	$ 462,129
6	2.69	$33,875	$33,504	$2,178,217	$37,625	$309,033	$122,100		$13,789	$11,295	$66,400	$2,805,838
Conn. 6-7	0.63	$ 5,000		$ 229,935	$ 9,500	$ 72,085	$ 9,450		$ 3,245	$ 3,930		$ 333,145
Conn. 6-8	0.63	$ 5,000		$ 181,415	$ 9,500	$ 71,180	$ 9,450		$ 3,204	$ 3,465		$ 283,214
7	1.36	$ 5,000		$ 309,915	$16,500	$155,486	$ 81,900		$ 6,963	$22,840	$10,950	$ 609,554
8	1.36	$ 5,000		$ 365,296	$16,500	$155,917	$ 56,400		$ 6,982	$24,675	$10,950	$ 641,720

Plate 3

ANNUAL ROAD USERS COST

All Alternates	Alternate	A Total Vehicles Ap + Ae	U Unit Cost Dollars/Mile	L Length In Miles	Road User Cost AxUxLx365
1978 ADT = 2458 Vehicles	1	3533	$.0930	2.08	$249,450
	Conn. 1-3	3533	$.0936	1.89	$228,126
Passenger Cars (Ap)	Conn. 1-4	3533	$.0937	2.13	$257,369
1978 ADT x 82.5% = 2028	2	3533	$.0941	2.08	$252,400
	Conn. 2-3	3533	$.0939	1.89	$228,857
Trucks & Buses (A_t)	Conn. 2-4	3533	$.0937	1.89	$228,369
1975 ADT x 17.5% = 430	3	3533	$.0977	2.61	$328,830
	4	3533	$.0979	2.18	$275,217
Equivalent Vehicles (Ae)	5	3533	$.0979	2.65	$334,553
A_t x 3.5 = 1505	Conn. 5-7	3533	$.0961	0.64	$ 79,312
	Conn. 5-8	3533	$.0958	0.63	$ 77,829
	6	3533	$.0975	2.69	$338,215
	Conn. 6-7	3533	$.0975	0.63	$ 79,210
	Conn. 6-8	3533	$.0976	0.63	$ 79,292
	7	3533	$.0949	1.36	$166,434
	8	3533	$.0949	1.36	$166,434

ANNUAL COSTS

Alternate	Right Of Way Est. Life = 50 Yrs	CONSTRUCTION			MAINTENANCE		Operating Cost	Total Annual Cost
		Grading & Draingage Est. Life = 40 Yrs.	Major Structures Est. Life = 40 Yrs.	Surfacing Est. Life = 20 Yrs	Interstate @ $3000/Mile	Frontage Roads @ $200/Mile		
1	$1,323	$ 11,559		$24,738	$6,240		$249,450	$293,310
Conn. 1-3	$1,837	$ 10,474	$ 6,318	$22,838	$5,670	$ 76	$228,126	$275,339
Conn. 1-4	$1,438	$ 11,503	$ 6,318	$26,214	$6,390	$208	$257,369	$309,440
2	$1,967	$ 17,327		$20,671	$6,240		$252,400	$298,605
Conn. 2-3	$ 509	$ 10,205	$ 6,650	$19,053	$5,670	$ 56	$228,857	$271,000
Conn. 2-4	$ 371	$ 10,438	$ 6,650	$19,925	$5,670	$246	$228,369	$271,669
3	$ 593	$106,745		$26,239	$7,830	$ 72	$328,830	$470,309
4	$ 248	$115,989		$21,979	$6,540	$ 72	$275,217	$420,045
5	$6,061	$133,815	$43,225	$24,974	$7,950	$160	$334,553	$550,738
Conn. 5-7	$2,550	$ 28,611		$ 6,556	$1,920	$ 50	$ 79,312	$118,999
Conn. 5-8	$1,669	$ 24,975		$ 6,552	$1,890	$ 60	$ 77,829	$112,975
6	$4,925	$163,976		$26,948	$8,070	$ 52	$338,215	$542,186
Conn. 6-7	$ 249	$ 17,099		$ 6,286	$1,890		$ 79,210	$104,734
Conn. 6-8	$ 220	$ 13,870		$ 6,207	$1,890		$ 79,292	$101,479
7	$2,142	$ 28,451		$13,558	$4,080	$ 16	$166,434	$214,681
8	$2,258	$ 30,439		$13,596	$4,080	$ 16	$166,434	$216,823

Plate 5